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REPORT OF THE

DEFENSE SCIENCE BOARD

TASK FORCE

ON

TACTICAL AIR WARFARE

NOVEMBER 1993

OFFICE OF THE UNDER SECRETARY OF DEFENSE
FOR ACQUISITION & TECHNOLOGY
WASHINGTON, D.C. 20301-3140

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Security review completed 15 December 1993 by OASD (Public Affairs) directorate for Freedom of Information and Security Review Case number 93-S-4403/M.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No 0704-0188
Exp Date Jun 30, 1986

1a REPORT SECURITY CLASSIFICATION Unclassified	1b RESTRICTIVE MARKINGS N/A
2a SECURITY CLASSIFICATION AUTHORITY N/A 2b DECLASSIFICATION / DOWNGRADING SCHEDULE N/A	3 DISTRIBUTION / AVAILABILITY OF REPORT Distribution Statement A. Approved for Public Release. Distribution is Unlimited.
4 PERFORMING ORGANIZATION REPORT NUMBER(S) N/A	5 MONITORING ORGANIZATION REPORT NUMBER(S) N/A
6a NAME OF PERFORMING ORGANIZATION Defense Science Board, Ofc of the Under Secy of Def (A&T) 6b OFFICE SYMBOL (If applicable) DSB/OUSD(A&T)	7a NAME OF MONITORING ORGANIZATION N/A
6c ADDRESS (City, State, and ZIP Code) The Pentagon, Room 3D865 Washington, DC 20301-3140	7b ADDRESS (City, State, and ZIP Code) N/A
8a NAME OF FUNDING / SPONSORING ORGANIZATION Defense Science Board, OUSD(A&T) 8b OFFICE SYMBOL (If applicable) DSB/OUSD(A&T)	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER N/A
8c ADDRESS (City, State, and ZIP Code) The Pentagon, Room 3D865 Washington, DC 20301-3140	10 SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. N/A; PROJECT NO. N/A; TASK NO. N/A; WORK UNIT ACCESSION NO. N/A

11 TITLE (Include Security Classification) Report of the Defense Science Board Task Force on Tactical Air Warfare, 1993 Summer Study, Unclassified.

12 PERSONAL AUTHOR(S)
N/A

13a TYPE OF REPORT	13b TIME COVERED	14 DATE OF REPORT (Year, Month, Day)	15 PAGE COUNT
Final	FROM N/A TO N/A	1993 November	89

16 SUPPLEMENTARY NOTATION
N/A

17 COSATI CODES			18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	

19 ABSTRACT (Continue on reverse if necessary and identify by block number)

20 DISTRIBUTION / AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21 ABSTRACT SECURITY CLASSIFICATION
22a NAME OF RESPONSIBLE INDIVIDUAL Diane L.H. Evans	22b TELEPHONE (Include Area Code) (703) 695-4157/8 22c OFFICE SYMBOL DSB/OUSD(A&T)

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

OFFICE OF THE SECRETARY OF DEFENSE
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DEFENSE SCIENCE BOARD

November 30, 1993

MEMORANDUM FOR THE UNDER SECRETARY OF DEFENSE (ACQUISITION)

SUBJECT: Report of the Defense Science Board Task Force on Tactical Air Warfare

I am pleased to forward the report of the Defense Science Board Task Force on Tactical Air Warfare which was co-chaired by Dr. Alexander H. Flax and Dr. John S. Foster, Jr.

A smaller contingent of this Task Force was convened originally to respond to the National Defense Authorization Act for Fiscal Year 1993 which directed that a technical assessment of particular issues related to the Department of Defense Tactical Aircraft Modernization Program be accomplished. A report of that Task Force's findings was forwarded to you last February.

Subsequently, an expanded Task Force addressed broader issues related to Tactical Air Warfare as one of the Defense Science Board's summer studies last August. Key findings are summarized in the memorandum from the co-chairmen which forwards the Task Force's report.

Paul G. Kaminski

Paul G. Kaminski
Chairman

OFFICE OF THE SECRETARY OF DEFENSE
WASHINGTON, D.C. 20301-3140

30 NOV 1993

DEFENSE SCIENCE BOARD

MEMORANDUM FOR THE CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Report of the Defense Science Board Task Force on Tactical Air Warfare

We are pleased to forward the report of the DSB Task Force on Tactical Air Warfare.

In addressing the findings of this report, we need first to highlight one point. It has to do with lessons from military conflicts in our country's history, especially lessons not learned. In every war, both sides are exposed to very costly lessons from mistakes and missed opportunities. History reveals that, unfortunately, many of the lessons are not learned and the same mistakes and missed opportunities are repeated in the next conflict. There are many reasons why this occurs but it doesn't have to continue now. To learn the lessons, actions must be taken to remove limitations and gain advantages over previous ways of conducting operations and acquiring new capabilities.

At the conclusion of the 1991 Gulf War, the DoD delivered to the Congress the report "Conduct of the Persian Gulf War," April 1992. It is noteworthy that, with respect to Tactical Air Warfare, that report calls for many of the actions this task force recommends. The lessons will not be learned until such actions are taken.

In this study the Task Force has emphasized the need to redress in the near term - over the next five to ten years - the most serious deficiencies in the systems and forces comprising our tactical air warfare capabilities. The greatest current imbalances in capability are in inadequate numbers of precision-guided weapons and associated target engagement systems, both on-board tactical aircraft and off-board sensors and associated data links. Among precision-guided weapons and platform delivery capabilities, the most important current shortfalls are in all-weather and standoff weapons, and we have strongly recommended that development and procurement of weapons in the latter categories be accelerated. There is substantial payoff for PGMs in that they require fewer sorties to achieve target destruction. Thus cost savings result not only from less munitions tonnage that needs to be delivered to the target, but also less fuel burned for the platforms required to go on the mission, and for the supporting aircraft that are also required. This payoff will have significant impact on the logistics system needed to supply particular scenarios.

However, the area in which we found the greatest opportunities for high-leverage improvements in tactical warfare effectiveness was in the integration of targeting and combat information systems linking JSTARS and other off-board sources of target information into a network capable of providing data directly to the weapon delivery platforms. The development of an effective end-to-end, wide-area surveillance and targeting system for both air-to-air and air-to-surface targets is essential. These systems should focus around AWACS and JSTARS

respectively and provide for rapid dissemination of multi-source surveillance and targeting data to all elements of the force structure. This ultimate capability will require improvements and integration of our current surveillance and targeting systems and the development of a tactical warfare systems information architecture for effective and timely distribution of the required data. We also believe that UAV systems should be explored more aggressively now in both development and joint operational exercises. These systems offer the potential for operations over hostile territory with reduced vulnerability and risk.

The Task Force emphasized that the need to maintain the balance among weapons, platform delivery capabilities, and target engagement and information systems will be more importment in the future than it is currently, and strongly urged that this perspective guide the overall tactical air warfare R&D programs of the Defense Department. Our overall Tactical Air Warfare capability depends on effective utilization of aircraft, weapons, off-board sensors, information distribution, and logistics systems. We need to establish the capability to evaluate trade-offs between different combinations of these systems. It should be noted that substantial and important near-term gains in our tactical air warfare capabilities do not require new aircraft programs to be achieved. Such gains can be achieved by equipping our current force with precision weapons and associated delivery systems and improving the surveillance and targeting, information distribution, and logistics support systems, making those forces much more effective. We must also exercise the resulting operational systems in realistic environments and demonstrate that we have learned the lessons of recent conflicts.

We would be happy to discuss the report with you at your convenience.

Alexander H. Flax
Alexander H. Flax
Co-Chairman

John S. Foster, Jr.
John S. Foster, Jr.
Co-Chairman

CONTENTS

GLOSSARY

AAA	anti-aircraft artillery
AGM	air-to-ground munition
AJ	anti-jam
ALCM	air-launched cruise missile
AMRAAM	Advanced Medium-Range Air-to-Air Missile
ARPA	Advanced Research Projects Agency
ASARS	Airborne Synthetic Aperture Radar System
ASD(C3I)	Assistant Secretary of Defense (Command, Control, Communications and Intelligence)
ASTOVL	advanced short take-off vertical landing
ATD	advanced technology demonstration
ATE	automated test equipment
ATR	automatic target recognition
AWACS	Airborne Warning and Control System
BDA	battle damage assessment
C3	command, control and communications
C3I	command, control, communications and intelligence
CAS	close air support
CEM	combined effects munition
CEP	circular error probability
CJCS	Chairman, Joint Chiefs of Staff
CINC	Commander-in-Chief
CINCCENTCOM	Commander-in-Chief, Central Command
CLO	counter low observable
CMT	critical mobile targets
COEA	Cost and Operational Effectiveness Analysis
DSB	Defense Science Board
ECCM	electronic counter countermeasures

ECM	electronic countermeasures
EMD	Engineering and Manufacturing Development
EMI	electro-magnetic interference
EO	electro-optical
ERP	effective radiated power
FOPEN	foliage penetration
G&A	general and administrative
GLONASS	Russian Satellite Navigation System
GOCO	government-owned/contractor-operated
GPS	Global Positioning System
HARM	High Speed Anti-Radiation Missile
IMU	inertial measurement unit
INS	inertial navigation system
IO	inventory objective
IR	infra-red
IRCM	infra-red countermeasures
JCS	Joint Chiefs of Staff
JDAM	Joint Direct Attack Munition
JFACC	Joint Forces Air Component Commander
JOPES	Joint Operations Planning and Execution System
JSOW	Joint Stand-Off Weapon
JSTARS	Joint Surveillance Target Attack Radar System
JTF	joint task force
LO	low observable
LPI	low probability of intercept
MRC	major regional contingency
NIE	National Intelligence Estimate
NTM	National Technical Means
OSD	Office of the Secretary of Defense
P3I	pre-planned product improvement
PGM	precision-guided munition
POM	Program Objective Memorandum

R&D	Research & Development
RDJTF	Rapid Deployment Joint Task Force
RF	Radio Frequency
SAM	surface-to-air missile
SAR	synthetic aperture radar
SFW	Sensor Fused Weapon
TRANSCOM	Transportation Command
UAV	unmanned aerial vehicle

BACKGROUND

TERMS OF REFERENCE

- Concepts for improved effectiveness
- Integration of tactical air assets
- Key leveraging technologies
- Exploit technologies to reduce costs
- Priorities for R&D
- Proper balance (Platforms, sensors, weapons, etc.).
- Key technology trades
- Commonality
- "Readiness"
- Joint Advanced Strike Technology Program

The terms of reference for the Tactical Air Warfare Task Force tasked the Defense Science Board (DSB) to review a fascinating set of the country's acquisition options for tactical air warfare over the next 10 to 20 years. (See Appendix A for Terms of Reference.) As the force structure is resized and restructured to meet the challenges of a disorderly new world order there will be opportunities for important new approaches and perspectives. More specifically, we were charged with exploring promising concepts and technologies that might provide high leverage in cost and effectiveness against foreseeable threats.

Our task force was organized to review as much of the spectrum of tactical air warfare as time would permit. Appendix B lists the members and panels. We began by analyzing historic trends in tactical air warfare. In those efforts we focused on the concepts of operations that were in practice, sought to discern how the then-current technologies drove us to employ those concepts, and sought to derive where the trends in operational concepts coupled with technology advancements might lead us.

We were asked to address the commonality issue. Since we addressed that subject in some detail in the earlier DSB report on Tactical Air Assessment (see Appendix C), we have nothing to add.

We were also asked to comment on the new initiatives specifically applicable to the Joint Advanced Strike Technology Program. The letter responding to the request for comments on this program is in Appendix D.

OVERVIEW

- History
- Perspective
  - What will stay the same?
  - What should change?
- Serious deficiencies
- Highest leveraged items
- Recommended actions

We began our analysis by reviewing the history of the kinds of capabilities we asked of tactical airpower in the past. In that effort we sought to understand how the capabilities supported those times' national objectives and how they were underwritten by what the current technology could provide then. We used the understanding gained by that review along with our vision of the direction of future technologies to suggest what types of programs might be especially valuable in the uncertain world of the future.

Much of our investigation and deliberation merely confirmed that the aggregate result of past decisions has produced a very effective force and most of the programs now in place will, in our opinion, do much to maintain military capabilities to meet challenges to U.S. national interests. These in-place programs support a number of tactical air warfare capabilities for which the need will stay the same in the foreseeable future.

However, there are areas that we believe require increased attention. These are the "What should change" items discussed in this report. We have identified deficiencies, some of which we know how to fix and others that will require additional research and development. From our analysis, we have developed a set of recommendations, based on technical/military objectives, that we feel address important areas where a change in approach or greatly increased emphasis is needed.

THE LEGACY SHAPING AIRPOWER - POST-WORLD WAR II

- National defense guidance - no more protracted land war involvement outside NATO - nuclear deterrence - more bang for the buck
- Tactical air focused on the nuclear mission
  - Designed for long-range, low-altitude, internal weapons - F-105, F-111, A-5
- Continuing doctrine-capabilities gap for conventional (non-nuclear) conflict
  - Little attention to conventional support of the land battle
- NATO orientation - drove USAF and Army thinking about conventional airpower concepts toward:
  - Air superiority over friendly territory
  - Interdiction of armored forces
  - Emphasis on choke points
- Little real change identified from Korean War operations
- Change initiated in late '50s and accelerated with the Kennedy administration - entered Vietnam in early stage of change

For several years following World War II, the guidance for national defense planning was to concentrate on protecting our vital national interests in Western Europe and to rely heavily on the nuclear deterrent to protect interests around the world.

In response to that guidance, the Tactical Air Forces, Air Force and Navy focused on the nuclear mission to the virtual exclusion of developing the conventional capabilities needed to underwrite air power doctrine. And to the extent that there was attention on conventional capabilities, it was increasingly concentrated on the NATO-Warsaw Pact confrontation. Given the formidable multi-layered ground-based defenses of the Warsaw Pact, U.S. air superiority aspirations were limited to NATO airspace with some hope for temporary superiority at times and places of our choosing in Warsaw Pact airspace. Ground attack capabilities had heavy emphasis on helping the ground forces deal with the expected massive attack by armored forces.

Even though the Korean War was a graphic demonstration of the limitations of the "more bang for the buck" nuclear deterrent umbrella, and it did lead to more emphasis on lower-yielded tactical nuclear weapons, that conflict was regarded as an aberration that did not warrant a significant contribution to improving conventional capabilities to deal with regional contingencies.

By the late 1950s, a number of influential military and civilian thinkers were providing persuasive arguments in favor of robust conventional capabilities. The Kennedy administration accelerated this trend but the forces available for the Vietnam conflict were in only the earliest stages of evolving to robust conventional capabilities.

THE LEGACY SHAPING AIR POWER - POST-VIETNAM

Focus on Post-Vietnam capabilities to underwrite air doctrine

- Common Army-Air Force air-land battle doctrine
- Realistic training - Top Gun, Red Flag, National Training Center, Composite Training Exercises
- High-intensity, nearly simultaneous strategic attack - no recovery time - freedom of friendly air operations
- Concentration of effective firepower vice just concentrating airplanes - precision strike/high lethality per sortie
- Rotary-wing firepower integrated with fixed-wing for both the close battle and support of deeper operations
- Transforming night from an enemy sanctuary to great advantage for U.S. forces
- Introduction of the first families of relatively low cost "smart weapons"
- Commitment to optimized systems for air superiority - essential for theater-wide freedom of operation for friendly forces

The lessons of Vietnam drove fundamental changes in focus. Senior air and ground commanders saw the need for a common air-land battle doctrine and began the long, painful process of working it out well before the end of the Vietnam conflict.

So-called combat ready forces required extensive additional individual and unit training and experience in the combat theater to become effective. The goal became to be effective on the first mission of the first day in future conflicts, and high priority programs were initiated to underwrite this goal.

The low lethality of individual attacks produced the need for large force packages to concentrate firepower and to provide defense suppression and protection against enemy fighter aircraft. The resulting pace of operations left the adversary with too much recovery capability between attacks. As a result, the strategic campaign did not achieve its objective. After Vietnam, the goal became the acquisition of capabilities enabling intense, fast-paced strategic campaigns.

While rotary-wing firepower in the actual conflict was rudimentary and of limited effectiveness, its potential was demonstrated and air-land battle doctrine and training began to focus on leveraging rotary-wing combat power with better integration of fixed-wing support.

Night was a time of virtual sanctuary from other than B-52 carpet bombing. By the end of the conflict, it was evident that developing technology could begin to meet the need for around-the-clock, high-intensity operations.

While intensified air combat training improved the performance of U.S. air superiority forces, it became painfully evident that U.S. fighter designs had been so extensively compromised for multiple missions that they could not provide the margin of superiority needed to win and maintain superiority over enemy territory. Poor air-to-air missile performance compounded the deficiency. All this led the Air Force and Navy to make aircraft optimized for air superiority and fleet air defense and lethal air-to-air missiles their top Tactical Air priorities. While optimized for the air-to-air role, these aircraft also had significant potential for strike and attack missions as needed. At the same time, the era of Vietnam and thereafter saw the introduction of new smart weapons such as laser-guided bombs.

THE LEGACY SHAPING AIR POWER - PRE-DESERT STORM

Special focus on Southwest Asia, 1980 to present

- Need for information superiority - surveillance, processing, communications
- Single CINC-centered air campaign
- Intense, continuous interdiction to isolate the battlefield
- More effective support of the close battle - focused CAS forces - attention to special demands for communications, survivability, and accurate weapon delivery
- Bomber, fighter, and rotary-wing aircraft evolved to capabilities cutting across strategic and tactical mission lines - moved towards seamless air power employment in Desert Storm - demonstrated as:
  - Air Force Special Ops and Army helicopters led the defense suppression effort the first night of Desert Storm
  - "Strategic" bombers provided battlefield air interdiction throughout the air campaign
  - "Tactical" fighters executed the strategic air campaign

The lessons of Vietnam and the demands of central Europe had much to do with the nature of the forces available for Desert Shield/Desert Storm. However, following the collapse of the Shah's government in Iran in 1979, there was also an intense focus on the special demands of Southwest Asia.

The senior leaders in the Rapid Deployment Joint Task Force (RDJTF) and its service components were veterans of the fragmented air effort in Vietnam with not one but six or seven air campaigns under the loosely coordinated direction of multiple senior commanders. It was clear that kind of fragmentation would spell disaster in Southwest Asia and, from the earliest exercises, the RDJTF commanders (Marine and Army) and subsequently CINCCENTCOM insisted on planning for a single CINC-centered air campaign.

The RDJTF's most demanding task was to deploy quickly and hold against a Soviet invasion of Iran. Given the vastness of the territory and the mission, it was clear that more knowledge of enemy activities would be an absolute prerequisite for success.

The same was true of the need to get the maximum leverage from rapidly deploying air power to slow the Soviet advance and add to the combat power of engaged ground forces.

The distances involved and the formidable task of stopping an invading force on the ground led to special emphasis on integrated planning of the use of all available air power, strategic bombers with gravity and stand-off weapons, Air Force, Navy, and Marine tactical fighters and Air Force, Navy, Marine, and Army rotary wing aircraft. From Korea to Desert Storm we saw the result of a long evolution towards the seamless integration of all air power that can add to the theater commander's combat power.

WHAT WILL STAY THE SAME?

The need to:

- Know the enemy (intelligence, surveillance, reconnaissance)
- Emphasize compatible joint doctrines, C3, and joint exercises
- Focus on readiness to deploy rapidly and sustain contingency forces
- Maintain decisive technical superiority in the face of proliferation
- Capitalize on the value of stealth
- Make incremental improvements in airframes, engines, avionics, etc., that provide leverage

As suggested earlier, here are a few important items from a far longer list where the current technical emphasis is on target and should be continued.

In the past we had a principal target for our intelligence, surveillance, and reconnaissance efforts. We cannot identify tomorrow's adversaries today, but our inability to do so does not diminish the "war" requirement to know the enemy. History has repeatedly provided evidence of how critical that knowledge is. We must have the resources that can be focused to acquire the information we need in a timely manner.

Also high on our list of areas for increased emphasis and smarter ways to leverage technologies is developing, proving, propagating, and practicing effective joint doctrine, command and control, and training. We have seen good progress on more effective joint doctrines, some progress in C3I, and far better understanding of the importance of Joint Task Force (JTF) level joint training and exercises. We will say more later about the promise of advanced distributed simulation in these areas.

The end objective of the C3 system is to provide the timely information needed for intelligent decisions at all levels, and to provide a rapid, effective target location and attack cycle. Technologies are available. Persistent focus and direction is needed. We also need some significantly different approaches to deciding priorities.

The current Defense leadership is focused on the essential elements that produce force readiness today, and modernization for force readiness tomorrow. We need to stay with that balanced approach.

Today, advanced technologies are available to any country with sufficient resources to pay the tab - witness the facilities and equipment that have been discovered in Iraq. In addition, the American public has been conditioned in two ways by the Desert Storm experience. First their expectations in the future will demand quick, decisive victories, and second, they believe (quite correctly) that the technological superiority brought to bear in that conflict was a prime contributor to the decisive win. Thus, we have proliferation of advanced technology weapons and a demand for technological solutions to cope with them. This confluence of factors requires us to maintain an edge over the capabilities residing in a diverse set of potential enemies.

Operational stealth successes in the Gulf War validated the initial judgments of those who supported development of this technology and its associated tactical warfare employment doctrine. Continued pursuit of this characteristic is important for vehicles that are to be operated in the face of enemy air defenses.

Incremental improvements in existing systems can make significant contributions to tactical air warfare capabilities. However, with current and projected fiscal constraints, new avionics, engines, weapons, etc., will be constrained to those that exploit new sets of technology in ways that make an essential difference in force capability.

SELECTED "WHAT SHOULD CHANGE" ITEMS

The need to:

- Know the capabilities of many potential enemies
- Emphasize capability to find and destroy ground targets
- Overcome institutional resistance to necessary tradeoffs
  - Improved vs. new systems
  - Multi-mission vs. single-mission platforms
  - Weapons and sensors vs. platforms
  - Logistics vs. weapon performance
- Emphasize a responsive integrated information architecture

And change, because we have some key deficiencies

In the past, we had a well-defined threat on which we could focus our intelligence and surveillance resources. Today, although no enemy is as formidable as the former Soviet Union, they are more numerous and we cannot focus on any single one. We saw in Desert Storm the value of having information superiority over our adversary. We will need those same advantages in any future conflict and must now acquire the capabilities to achieve the requisite knowledge about a variety of potential enemies.

The capability to find ground targets under a range of environmental and tactical circumstances has not kept pace with the remarkable advances made in aircraft platform and precision guided weapon performance. In addition, current guided weapons do not provide all-weather capability. Destroying ground targets surely and efficiently, even under adverse weather conditions, offers great leverage in affecting the outcome of the military and political situation. We believe priority should go to the target location end of the tactical air warfare system. Further, current plans for investment in precision guided weapons are not commensurate with their high payoff. This justifies some shift in TacAir programs investment away from the more traditional focus on the aircraft platform and its performance.

The DoD "institutional bias" heavily favors new systems with more emphasis on platform programs than on architectures for information flow, sensor improvements and weapons programs. Also, logistics does not claim the attention of the operational decision makers that dominate the requirements process. Still, there are any number of reasons for shifting attention from new systems to improved systems and logistics. In most areas, there is significant growth potential left in the latest existing systems, especially when viewed from an end-to-end system perspective. We can afford only a few new systems and the time required to field new systems also argues for attention to improvements.

The payoff from precision guided weapons needs no further proof although continued emphasis on acquisition programs is necessary. That payoff shifts the dominant challenge from lethality against targets, which now is technologically well in hand for most targets, to target location/identification and battle damage assessment (BDA). Hence the need for focus on sensors and C3 systems. The keystone for success across the board, from acquisition decision to combat effectiveness, lies in a fully responsive, integrated Tactical Warfare Systems Information Architecture.

We also have additional deficiencies that we have grouped into two types: serious ones that have known technical solutions and serious ones requiring research and development priority.

SERIOUS CURRENT DEFICIENCIES THAT HAVE KNOWN TECHNICAL SOLUTIONS

- Lack of integrated battlefield surveillance/reconnaissance
  - Off-board sensors and data links to improve targeting
- Vulnerabilities of critical sources of information (GPS, JSTARS, AWACS, E-2C, etc.)
- Inadequate quantities of PGMs and their delivery systems
- Inadequate quantities of standoff weapons
- Lack of a joint exercise environment that integrates simulators, wargames, and distributed live forces
- Lack of superior air-to-air missile

It is clear that there is no technical barrier that prevents us from fielding a battlefield surveillance/reconnaissance/targeting system that collects the data acquired by different platforms and different sensors, integrates it, fuses it, and passes it via links to shooters. Though there is no technical barrier, our fighting forces do not yet have this needed capability.

As the large information and C3 platforms become more important to the effectiveness of our forces, countering them will become more important to adversaries. Given the proliferation of Russian long range air-to-air and surface-to-air-missiles (SAMs) as well as electronic warfare systems, we need intense focus on making our systems more survivable and resistant to electronic countermeasures.

In the future, with digital communications, packaging, and information systems making it possible to have robust, cooperative systems that are more robust because of their using both on- and off-board elements and UAVs, these large platforms can become less vulnerable and less lucrative targets for our enemies.

The principal issue with precision-guided munitions (PGMs) and cruise missiles is the need to accelerate procurement rates and make the delivery systems, fighters, and bombers compatible with the weapons and capable of adequate target acquisition and MIL-STD-1760 wideband bus weapon delivery. Incremental improvements in planning responsiveness and delivery capabilities can make a very significant difference. A second PGM issue is the urgent need for an adverse-weather capability against fixed, mobile, and moving targets; laser-guided weapons can have disabling problems in all but quite clear conditions.

Challenges to national interests inevitably will demand high-risk missions while, at the same time, there will be low tolerance for high losses. At least in the early phase of attacks, stand-off weapons are likely to become the weapon of choice more often than in the past. There is a need to increase precision, lower collateral damage, and shorten mission preparation time.

Of great importance is accelerating the introduction of advanced distributed simulation technology to leverage joint force training and exercises. Those technologies will provide significant enhancement to live force training in the field of a size that is affordable and appropriate to the training areas. The technology also will allow individuals at distributed locations (such as National Guard Armories or in regional virtual simulation training facilities) to participate through connected virtual simulations. It will allow the use of virtual simulations and computer-driven forces and wargames to expand the challenge to the brigade, division, or JTF.

The final bullet of the chart concerns the fact that our currently-operational air-to-air missiles do not have performance characteristics that make them clearly dominant over foreign counterparts. Technology is available that could be fielded in the near-term to rectify this situation and should be incorporated as part of the AIM-9X program and AIM-120 product improvement.

SERIOUS CURRENT DEFICIENCIES REQUIRING RESEARCH AND DEVELOPMENT PRIORITY

- Inability to:
  - Locate/destroy critical mobile targets
  - Locate/destroy Tactical Ballistic Missiles
  - Destroy hardened, buried, and tunneled facilities
- Theater and ship air defense against low-observable cruise missiles
- Vulnerabilities of a commercially-based information distribution system

In Desert Storm, the unreliable and inaccurate Iraqi tactical ballistic and cruise missiles achieved more psychological and propaganda value than military impact. But, the proliferation of far more effective classes of these systems is inevitable. It is a difficult problem. But, there are a number of potential technological solutions or contributors to the solution that ought to be receiving high priority.

We see militarily significant facilities in countries around the world being hardened, buried, or sited in tunnels and caves. In particular, vital command and control capabilities are likely to be deeply buried, denying our forces the ability to strike very-high-payoff targets. There are deep penetration concepts that ought to be pressed harder to mitigate this deficiency.

Over time, some significant capability to exploit low-observable (LO) technology inevitably will proliferate. As evidenced by the Stark incident, the French EXOCET, possessed by and available to many Third World countries, presents significant challenges to our target acquisition and engagement systems. Cruise missiles are particularly well suited to LO treatments and are likely to lead the way in reduced observability and be an increasing threat to our forces.

And finally, as DoD increasingly migrates the information distribution workload to a commercial base, concerns about vulnerabilities of commercial systems must be addressed. Commercial satellite communications vendors are not building anti-jam or data integrity features into their systems. Commercially-developed computers, networks, and software are vulnerable to viruses and other forms of information tampering and intrusion, especially when used in the geographically distributed configurations that the tactical air community will require. Ensuring flexible access to needed data in the right place, at the right time, and at an appropriate security level will require access controls and information protection not offered routinely by today's commercial vendors. The government and commercial sectors are currently conducting limited research into promising security concepts. This R&D effort should be expanded significantly to reduce the vulnerability associated with a commercially-based information distribution system, both to prevent denial of service as well as to prevent information leakage.

HIGHEST LEVERAGE ITEMS

HIGHEST LEVERAGE ITEMS FOR IMPROVED TACAIR WARFARE CAPABILITIES

- Equip the force
- Improve logistics effectiveness and efficiency
- Exercise our operational capability
- Define and implement a tactical warfare systems information architecture
- Perform capability trade-offs

We now address the highest leverage items shown above. First, under equipping the force, we examine problems and potential solutions concerned with the lack of an end-to-end, wide-area surveillance, not enough aircraft equipped to use advanced PGMs, acquisition of PGMs, and the vulnerability of Global Positioning System (GPS) receivers to jamming. In the logistics and industrial capability section, we address problems and potential solutions related to deficiencies in wartime capabilities, excess industrial capacity, unnecessary specialization of aircraft field maintenance systems, and the inadequate exercising of our logistics capability. We then address the need to exercise our operational capability and follow that with the necessity to define and implement a tactical warfare systems information architecture suited to the new defense environment. Finally, we address the need to define and perform trade-offs among different categories of weapons, systems, and platforms.

EQUIP THE FORCE

Problems:

- Lack of an effective end-to-end (detection-to-destruction), wide-area surveillance and targeting system
- Too few combat/strike aircraft have capability to use advanced PGMs
- Planned PGM acquisition rates and total buys are inadequate
- GPS receivers are vulnerable to jamming

There are a number of deficiencies and problems associated with the current Tactical Air Warfare force structure.

The high leverage offered by employment of precision-guided weapons is restricted by the C3I infrastructure for acquiring targets on the battlefield, identifying them, locating them in GPS coordinates with accuracy suitable for weapon launch, and disseminating targeting data to the shooters in a timely manner. Military forces currently lack an effective end-to-end, wide-area surveillance and detection-to-destruction targeting system, and current plans will not provide this capability.

Insufficient numbers of existing combat/strike aircraft are equipped with the capability to deliver PGMs. The projected acquisition rate and total buys for targeting pods are inadequate to redress this deficiency. For example, less than half the F-16 force will be equipped by 2000, none of the AV-8B fleet has PGM targeting pods, and the planned acquisition rate of targeting pods for the F/A-18 is too low.

Both the projected acquisition rates and total buys for future precision-guided weapons are inadequate. The Joint Direct Attack Munition (JDAM) and Joint Stand-Off Weapons (JSOW) acquisition programs are on such a slow pace that militarily significant quantities will not be available until well after fiscal year 2000. The impact of these deficiencies, if a major contingency occurs, is that both greater numbers of sorties will be required per target killed and there will likely be higher aircraft and aircrew attrition.

Most tactical aircraft and weapons will employ some form of GPS navigation. GPS has the potential to provide a substantial advance in accurate, all-weather delivery capability. However, GPS receivers are uniquely vulnerable to jamming since the satellite transmitter is three orders of magnitude further away than likely jammers. Modest (few watt) GPS jammers can deny acquisition at very long ranges (hundreds of kilometers).

EQUIP THE FORCE - SURVEILLANCE AND TARGETING

Recommend:

- Develop an end-to-end, wide-area surveillance and targeting acquisition system
  - Develop JSTARS as control center for targeting
  - Improve JSTARS SAR resolution by at least 3 to 1
  - Develop SAR/GPS relative targeting concept
  - Transition some Warbreaker technologies for CMT targeting
  - Continue work on reduction of NTM data timelines to shooters (Talon Sword/Talon Zebra)
  - Improve sensor systems for theater surveillance in denied/defended areas (e.g., UAV SAR systems)

As noted on the previous page, our present theater C3I is inadequate to meet the timeliness challenges presented by today's battlefield, let alone tomorrow's. Part of this infrastructure resides in theater surveillance assets such and Rivet Joint, Joint Surveillance Target Attack Radar System (JSTARS), and the TR-1, but these systems need integration into an overall theater targeting system, to make their timeliness operationally suitable. Additionally, we need the communications infrastructure for data and imagery transmission to shooter platforms.

We recommend making JSTARS a control center to integrate selected data from off-board sources [e.g., National Technical Means (NTM), Rivet Joint, Airborne Synthetic Aperture Radar System (ASARS)] and ground target attack. We need to establish a data link from JSTARS to strike aircraft to pass target data and even high-resolution images.

Current JSTARS resolution is inadequate for target identification in the synthetic aperture radar (SAR) mode. We need to improve it at least 3 to 1 to enhance capability for identifying time-critical targets (roughly $100M R&D plus $100-150M procurement).

Many of our high-quality attack aircraft have SAR capability that can be modified to permit JDAM-like weapons to be used against mobile but non-moving targets, by using SAR-derived target location data to define a local GPS coordinate system for both the aircraft and weapon, which eliminates the normal GPS target location error. If the attack can be prosecuted during the time interval when the same set of GPS satellites are in view, the weapon accuracy can be as little as five meters. More important, this can provide the ability for mobile target kill prior to the time terminal sensors might be available for the weapons themselves. (This capability could be achieved at roughly $25M R&D per aircraft type.)

These surveillance assets have limited capability to provide target data in denied or defended areas. At present, we must rely upon NTM to provide coverage, which though useful, is not the continuous coverage necessary for may types of targets (e.g., SCUD launchers). A penetrating, air-breathing sensor platform could provide the coverage, e.g., unmanned aerial vehicles (UAVs) with low probability of intercept (LPI) SAR, or a bi-static SAR system. Although it might be post-2000 before we get such a capability, it is important to get it started now.

The ARPA Warbreaker program is a key source of concepts and sensor systems to prosecute attacks on critical mobile targets (CMT). Probably the most critical technical issue is to develop automatic target recognition (ATR) techniques with performance adequate to maintain acceptable false-alarm rates, when surveying large land areas. Warbreaker's objectives include finding targets that are concealed and\or camouflaged, and in foliage. However, there are many targets that are much easier to find (e.g., SAM sites), particularly when cueing information is available. We recommend the transition of certain selected Warbreaker Technologies now - e.g., ATR algorithms for targets in clear areas, specialized ATR for

strictly limited sets of very important mobile targets (this would require approximately $25M in R&D cost.)

Demonstration programs (e.g., Talon Sword, Talon Zebra) have shown that the C3 infrastructure can enable timely utilization of national assets. These efforts should be accelerated with emphasis on useability of national sensors for mobile targeting.

EQUIP THE FORCE - UAVs

Recommend:

- Develop and assess UAV-based surveillance and targeting systems, and deployment concepts utilizing existing vehicles
  - Use computer emulation and CINC participation to evolve sensor payload characteristics
- Pursue three classes:
  - A high-altitude, long-endurance platform for long-range surveillance and target ID, as an adjunct to JSTARS
  - A low-altitude platform with EO/IR, laser designator, and with FOPEN SAR sensor system option
  - A short-range, small-payload UAV (already in low-rate production)
- Develop and have users evaluate brassboard prototype sensor systems
- Procure limited number of UAV systems for operational tactical user performance evaluation (joint exercises)
- ARPA should explore the possibilities of UAVs in air-to-air combat through simulations and modeling to discover promising concepts

We believe UAV systems may not be sufficiently exploited by the Services in spite of the current joint UAV programs. With the sensor and laser technology available today, existing UAV systems could leverage contingency force operations with reduced vulnerability and risk. Several classes should be explored aggressively.

- One class is a long-endurance UAV that normally operates at medium altitude, to see beyond JSTARS coverage, with a duration of 12+ hours. It will need radar to see through the clouds and another payload for foliage penetration (FOPEN). The sensor package should be based on currently available technology; a demonstration air vehicle can be one that is already developed.
- The second class is a UAV that operates below clouds to supplement penetrating tactical reconnaissance. It has electro-optical/infra-red (EO/IR) sensors and lasers to designate targets for attack with laser-guided weapons, and could have FOPEN SAR if necessary. It should be derived from available technology. Again, existing platforms should be able to accommodate the needed payload.
- The third class of UAV already exists. These are short-range UAVs under the cognizance of Army/Marine commanders. We need open-minded tests and evaluation by users to determine their utility and approaches to exploit their current capabilities.

DoD should initiate programs to develop and field improved sensor packages to meet these needs, as soon as the concepts are validated. Early user involvement is essential, including simulation and joint exercises, to refine and evolve the design and operational employment doctrine and tactics.

ARPA should explore the possibilities of UAVs in air-to-air combat through simulation and modeling to discover promising concepts for prototyping and demonstrations.

EQUIP THE FORCE - UPGRADE EXISTING AIRCRAFT

Problem:

- In Desert Storm PGMs were 12-20 times more effective than dumb bombs, but based on POM 94, <45% of TacAir will have adequate PGM capability

Recommend:

- Accelerate buys of targeting pods and other essential aircraft modifications so more F-16Cs, F/A-18Cs, and AV-8Bs can employ current and developing PGMs effectively
- Provide F-14D, F-15C, and F-22 interceptor and air superiority aircraft with effective air-to-surface PGM capability

In a "zero-sum" budget environment, DoD should emphasize leveraging upgrades to existing aircraft over new aircraft development. For example, less than 45% of DoD's air-to-surface aircraft have adequate PGM delivery capability from medium altitudes and, with current weapon acquisition and aircraft modification/acquisition plans (POM 94), this will not change until well after FY 2000 (when JDAM/JSOW should begin to become available in quantity).

- Widely proliferated man portable SAMs and AAA drive most air strikes to medium altitudes
- In Desert Storm, PGMs were 12-20 times more effective than dumb bombs

At least five additional wings of F-16s need PGM pods and PGM delivery capability, which includes the wideband 1760 bus (about $2 to $3 billion, FY 1995-02).

Pod procurement rates should be accelerated for the F/A-18C/D (from the planned low rate of 20 to 40 pods per year to about 80 per year, adding 160 pods for about $350M, FY 1995-99).

Given the proliferated MANPADS threat, the AV-8B will need a capability for accurate weapon delivery from beyond 15,000 ft slant ranges. At present, no pods are planned for the AV-8B fleet, inhibiting its ability for target acquisition and PGM delivery (e.g., LGB, JDAM, JSOW). We recommend adding about 100 pods and related aircraft modifications for effective PGM delivery capability (about $400M, FY 1995-00).

We support plans to modify F-14D, F-15C, and F-22 aircraft (currently focused on air-to-air capabilities) to enhance their air-to-surface PGM capability, thereby enabling these assets to be more valuable once air superiority is established. The F-22 should incorporate air-to-surface capability from the start and F-14D and F-15C modifications should be accelerated (about $100-150M R&D per aircraft, plus modest recurring cost).

EQUIP THE FORCE - PRECISION-GUIDED MUNITIONS

Problem:

- PGM acquisition plans for fighters and bombers are inadequate in the near term (prior to FY 2000)
  - Only 50% of PGM air-to-surface weapon inventory objective will be met by FY 1999
  - Only about 5% of PGM inventory will be all-weather capable (excluding HARMs)

Recommend:

- Increase buy of PGMs in near-term weapon acquisition plans
  - Accelerate PGM procurement rate to buy inventory objective by FY 2000 and increase acquisition rate of all-weather PGMs
  - Higher priority for longer range, stand-off, all-weather PGMs
  - OSD and Services review the PGM inventory objective
  - Field contingency quantities of JDAM earlier than planned for initial user evaluation
  - Develop and buy guided dispenser for accurate medium-altitude cluster munitions delivery
- Increase emphasis on the development of improved stand-off, all-weather precision attack capabilities, including integration of target acquisition, target engagement and weapons for fixed, mobile, and moving targets.

We compared planned Air Force and Navy/USMC weapon inventories in FY 2000 with weapon inventory objectives (IOs) based on new Post-Cold War requirements and found PGM acquisition plans for fighters and bombers are inadequate in the near term (i.e., prior to FY 2000). Desert Storm has had a minimal effect on Service plans to increase PGM inventory levels. Even the Service's modest objectives are not being bought. For example, only half of the PGM air-to-surface IO (POM 94) will be met by FY 1999 and only 5% of the PGM inventory will be capable of effective all-weather target kill. We believe that Service IOs for PGM quantities are too low, but we did not examine Service weapon inventory methodologies in detail.

PGMs could reduce wartime logistics requirements. In some contingencies, wide use of PGMs could result in fewer sorties and/or shorter conflicts, thus reducing logistics needs. For example, Gulf War experience showed that for many types of targets, a ton of PGMs typically replaces 12-20 tons of unguided munitions on a tonnage per target kill basis. Correspondingly, taking into account the totality of air operations, as much as 35-40 tons of fuel per ton of PGMs delivered may be saved.

DoD should accelerate acquiring a weapons inventory much more focused on PGMs:

- Given the scarcity of stealth aircraft for the foreseeable future, leverage the 2,000-3,000 aircraft in the force by placing a higher priority on longer range, precise standoff weapons and targeting capabilities, including operating effectively in all-weather.
- Accelerate fielding of contingency quantities (1,000-2,000) of JDAM by using a fast-track acquisition approach, including early user testing and employment prior to formal Operational Test and Evaluation.
- Increase procurement rates of existing PGMs, especially PAVEWAY 3, AGM-130, and SLAM in FY 1995-99.

PAVEWAY 3 guidance is needed for all I-2000 bombs in order to control impact angle and avoid their breakup on impact. PAVEWAY 3's small circular error probability (CEP), 10 ft., makes it valuable for a wide range of tactical targets as well as those strategic targets that require small CEPs. A modest buy would include 20,000 PAVEWAY 3 kits at about $1B, 300-500 additional SLAMs at about $250-400 million, and 300-500 additional AGM-130 at $150-250 million, FY 1995-00.

- Using a fast-track approach, develop and procure contingency quantities of a guided dispenser for medium-altitude accurate delivery of sensor fused weapons (SFWs) and combined effects munitions (CEMs) from all air-to-surface platforms, and place them in the hands of operators for experimentation and possible contingency use (e.g., about $100 million for R&D and 1,000 weapons).

DoD should accelerate the development of a standoff, all-weather, precision air-to-surface weapon.

EQUIP THE FORCE - VULNERABILITY TO GPS JAMMING

Problem:

- Current GPS receivers are vulnerable to jamming in acquisition mode at very long range from low power jammers and will lose track at moderate range for reasonable jammer threats

Recommend:

- Provide at least half the strike aircraft platforms with improved GPS ECCM capability (selective receivers, GPS/INS coupling, adaptive antennas)
- OSD should perform a critical review of the impact of GPS ECM vulnerability on JSOW and other weapon mission effectiveness
- Create an independent GPS vulnerability assessment group led by OSD
- Aggressively pursue countermeasures to adversaries' use of GPS

Most tactical aircraft and weapons will employ some form of GPS navigation. GPS has the potential to provide a substantial advance in accurate all-weather-delivery capability. However, GPS receivers are uniquely vulnerable to jamming since the satellite is three orders of magnitude further away than the jammer. A small, few-watt jammer can be cheap and easily deployable, while a few hundred-watt ERP jammer can be relocatable. Jammers in the few-kilowatt-ERP range start to become high-value targets.

Modest (few watt) GPS jammers can deny GPS acquisition at very long ranges (hundreds of kilometers). GPS receivers should not attempt acquisition under conditions where jamming is likely.

Tactical aircraft delivering GPS-aided weapons require significant levels of electronic counter countermeasures (ECCM) improvement if they are to avoid GPS track loss and properly initialize their weapons. Tighter coupling of GPS/inertial navigation system (INS), improved selectivity receivers, and adaptive antennas each will provide anti-jam (AJ) improvements. If all of these techniques are employed, strike aircraft can be made invulnerable to almost all potential GPS jammers.

For shorter-range missiles, such as JDAM and JSOW, a jammer could break GPS track. DoD should carefully review the JSOW ECCM issue to determine whether the proper balance has been struck among ECCM vs inertial measurement unit (IMU) quality vs. standoff range in an electronic countermeasures (ECM) environment.

Modern weapon systems will be dependent on the GPS system. The vulnerability of any system to denial of GPS must be considered a first-order issue in decisions associated with the design, procurement, test, evaluation, and deployment of the system. A high-level DoD group should be established to assess the vulnerability of future systems to the denial of GPS. Also, because there will be extensive world-wide proliferation/use of GPS for navigation, DoD should pursue development of countermeasures to potential adversaries' use of GPS/GLONASS.

EQUIP THE FORCE - PGM IMPLEMENTATION

The combination of an integrated end-to-end surveillance and targeting system and the expanded use of PGMs will improve Tactical Air Warfare effectiveness more quickly than any other set of measures.

- Implementation cost is approximately $1B/year for 5 years
- For a major conflict, this investment could pay for itself through reduced sorties per target killed, shortened combat time, reduced aircraft and aircrew attrition, and lower wartime logistic costs
- Upgrading existing combat aircraft with PGM capability makes it much more probable that the planned reduced tactical air force structure could conduct two MRCs simultaneously
- Near-term sources of funds are attainable by modest rescheduling of tactical air related programs

Desert Storm showed the great potential of wide-area surveillance and targeting, as well as the weaknesses in our current capabilities. Desert Storm also showed that a small fraction of our assets (mostly F-117s, F-111s, and A-10s) accounted for a majority of the strategic and tactical battlefield targets that were destroyed. Most other aircraft, dropping unguided ordnance from medium altitudes (to avoid the low altitude threats), were largely ineffectual.

The highest payoff near-term action DoD can take to increase the air-to-ground effectiveness of our tactical air forces is to: 1) define, field, and evolve an effective end-to-end target surveillance and targeting system; 2) expand our PGM delivery vehicle capability; and 3) buy enough PGMs for a reasonable campaign.

The cost of these upgrades is about $1B per year for a 5-year period. This amount represents a small fraction of the life-cycle cost of that force and could yield an effectiveness increase of a factor of ten to twenty.

For a major conflict, this investment could pay for itself through drastically reduced sorties per kill, shortened combat time, reduced aircraft and aircrew attrition, and lower wartime logistic costs. Moreover, this investment makes it much more likely that our reduced tactical air force structure could effectively conduct two major regional contingencies (MRCs) simultaneously.

EQUIP THE FORCE - AIR-TO-AIR MISSILES

Problem:
- Our current capabilities are not superior to our foreign counterparts
- Improved versions of both our short-range and medium-range missiles will not be available until the late 90's and beyond

Recommend:
- Move forward on AIM-9X program to get enhanced range, maneuverability, and ECCM capability
- Increase priority upgrades for AMRAAM to enhance capability to counter combination of LO and endgame countermeasures

Gaining and maintaining air superiority - hopefully air supremacy - is the first priority of our air forces, achievement of which enables our surface forces to operate without fear of air strikes. If our Offensive CounterAir and Attack Operations missions do not succeed in "pinning in" enemy combat aircraft, our air forces will need to conduct air-to-air combat. Even with the benefit of our likely superior off-board warning and control assets (e.g., AWACS, Rivet Joint, etc.), which should enable our air superiority aircraft to position themselves favorably, our combat aircraft may be forced into air-to-air combat.

Should that occur, our air forces may be "outgunned," because presently the U.S. does not enjoy a position of technical and military superiority over all foreign air-to-air missiles. This is particularly true for the short-range IR guided missiles (AIM-9M), for which the U.S. basically abandoned new missile development approximately 15 years ago due to international development agreements. Russian and French missiles substantially outclass the AIM-9 kinematically, operationally, and in infra-red countermeasures (IRCM) resistance. In the medium-range (AMRAAM) missile arena, advanced versions of the Russian AA-10 missile have a longer range capability than ours.

Our new short-range missile program (AIM-9X) seems to be moving in the correct direction, but at a pace that is inconsistent with our perception of the seriousness of the deficiency. We recommend a faster acquisition program focused on enhanced range, maneuverability and ECCM.

To make AIM-9X "better" than the AA-11, MICA and Python might add $200-300M to the $1-1.2B likely AIM-9X RDT&E cost and probably $75-100K per missile (approximately $250K each instead of $150K to $175K each). But one cannot look at round cost alone. One must add in the effect of fewer lost "Blue" aircraft, to offset the extra cost of the round (one F-15 saved - at $50M each - pays for the likely difference in cost of 500 missiles).

We believe the AMRAAM preplanned product improvement (P3I) program, intended to result in substantially improved kinematics and ECCM, is moving at a too leisurely pace. We recommend a more aggressive acquisition program.

Furthermore, we believe there is a major future issue of how best to deal with a combined thrust of LO and endgame countermeasures. When employed with LO vehicles, noise jamming waveforms can deny use of range and Doppler resolution. Purely seeker-based solutions to this problem are very complex and expensive, and may not even work, particularly in obtaining all-weather, all-aspect capability. We believe a study of how best to deal with this problem, which strikes a proper balance between faster autopilot response time, maneuverability, new warhead technology, and seeker complexity, is needed to define the appropriate long-term P3I solution.

EQUIP THE FORCE - COUNTER STEALTH R&D

Problem:
- How to avoid technical surprise and maintain contractor competence
  - Lack of near-term technology transition opportunities discouraging sponsors

Recommend:
- Need to maintain vigorous Counter-Low Observable (CLO) hedge program
  - Need flying testbeds with operationally oriented demonstration objectives

It is our belief that TACAIR force elements eventually will have to face up to a reduced observables threat. The impact of reduced radar cross-section on important weapon systems such as AWACS, F-15, AMRAAM, etc., can be devastating. In recognition of this possibility, substantial effort and money has been spent over the past several years to develop options for dealing with the LO threat. The threat has not yet manifested itself in a serious way, and might not do so for an indefinite time.

In the current budget environment, it is difficult to predict the circumstances in which we would transition acquisition programs such as those for air defense components with substantially improved CLO capability (e.g., a new AWACS) from Milestone I - Concept Development Phase to Milestone II - Engineering and Manufacturing Development (EMD) phase. As a consequence, there is little opportunity for the current CLO technology programs to transition to EMD, and this is discouraging to current sponsors of those programs in the existing fiscally constrained environment.

We believe it is important to continue the technology development in this area beyond those threats contemplated in the National Intelligence Estimate (NIE) and without pressures for transition to EMD that the current climate dictates. In particular, this critical technology area needs a "hedge" program to avoid technical surprise (in the programmatic sense). We fear that if current R&D efforts were discontinued or reduced to component R&D efforts, our ability to respond to the appearance of a significant LO threat would be lengthened by at least 4 years, because the contractors would have lost their technical edge. Substantial demonstration activity would have to be repeated.

Because much of the "art" in achieving CLO capability involves system integration issues, we believe that a continuing technology base and advanced development programs utilizing a series of flying testbeds are needed to maintain and extend technological competence. Also, a continuing series of demonstration objectives with strong operational flavor is required to focus the programs. The ACTD concept recently espoused by OSD is applicable here.

This is an inexpensive suggestion, though the conversion of the current R&D efforts into a long-term "hedge" effort will require serious thought about restructuring them into a fiscally sustainable program.

EQUIP THE FORCE - PLATFORM TECHNOLOGIES

<u>Problem</u>:

- Projected DoD budget limitations do not permit acquisition of varied types of new tactical aircraft at rates sufficient to maintain the planned force structure

<u>Recommend</u>:

- Near-term, focus on common engines, avionics, weapons, and support
- Longer-term, explore potential advances in system design and manufacturing technology to achieve a viable common tactical aircraft
- Continue ASTOVL technology demonstration
  - Develop suitable exit criteria
  - Develop rational performance goals

Multi-Service/Multi-Mission Common Aircraft/Common Components:
There are recurring pressures to procure tactical aircraft that can be effectively employed by all Services. A common aircraft is one that, from an acquisition standpoint, has a single design that employs a common airframe and engine, although some removable modules, such as avionics, may differ. Conversely, aircraft that have different airframe designs, although incorporating many identical components, are not considered common aircraft.

There are many reasons why inter-Service commonality has not been achieved. Service operational requirements and design specifications are developed in separate organizations and thereby optimized to different perceptions of need. Historically, Service replacement milestones for aircraft of similar type have not coincided, and the benefits and penalties of full commonality have not been quantified in a way to allow a convincing cost-effectiveness rationale. Indirectly, industrial and technology base considerations also mitigate enthusiasm for such an airplane.

While a fully common tactical aircraft may be an achievable long-term goal and a concept worthy of exploration, we believe that the near-term focus should change from a fully common tactical aircraft to a substantially common airplane that employs common engines, avionics, and test and support equipment, but may have some airframe differences to accommodate unique Service needs. The Task Force's comments on the recently initiated JAST Program, which includes advanced development platform technologies, are contained in Appendix D.

Advanced Short Take-Off Vertical Landing (ASTOVL):
In project development, ARPA has understandably endeavored to make the ASTOVL demonstration aircraft as relevant as possible to future Service requirements, leading to its frequent description as "the prototype for a common Service strike-fighter." We are concerned that this characterization may prove misleading, since an advanced technology demonstration (ATD) does not attempt to meet the milestone requirements of an acquisition program, such as validation of an operational requirement or "surviving" a Cost and Operational Effectiveness Analysis (COEA).

To optimize the ASTOVL ATD, we recommend that the ARPA project goals be clearly stated and include an explanation of how their attainment will contribute to future Service aircraft program development. Criteria should be developed for use at milestone reviews to adjust ATD performance objectives (such as supercruise and LO) or exit the project. Subject to these criteria, we believe this ATD has potential payoff and should be continued.

LOGISTICS AND INDUSTRIAL CAPABILITY - KEY DETERMINANTS OF READINESS

Problems:

- Long-term, persistent, and serious deficiencies in wartime capabilities
- Excess private and public sector industrial capacity
- Unnecessary specialization of aircraft field maintenance systems (e.g., automatic test equipment) and inaccurate troubleshooting
- Inadequate exercising of logistics capability

Logistics is a key to readiness. It prepares us for battle, gets us to war, and keeps us operating. In the Gulf War, our aircraft were well supported and, except for some sand damage to helicopter components, sustained high operational readiness rates throughout.

Yet, we have some long-term, persistent, and serious deficiencies in our capability that hamper our ability to plan and support contingency operations. They include inabilities to rapidly plan and execute deployments of large forces, to track shipments of cargo to the theater of operations, to move material from the ports and airfields of top military units, and to effectively manage munitions. These lessons were learned from the Vietnam experience. Twenty years later, still uncorrected, they were lessons to be learned again in the Gulf War.

We also have an industrial base, in both DoD's maintenance depots and in the private sector, that far exceeds DoD's needs. DoD pays the cost of that excess capacity.

By addressing overspecialization of field maintenance systems and troubleshooting problems, we have some opportunities to improve the efficiency and effectiveness of aircraft support, making it both more affordable and better suited to contingency operations.

Finally, we do not exercise our logistics capabilities sufficiently enough during peacetime to understand their limitations and effects on military operations.

LOGISTICS AND INDUSTRIAL CAPABILITY - KEY DETERMINANTS OF READINESS

Recommendations - Wartime Logistics Capability:

- Assure continued attention, funding, and priority to correct deficiencies in:
  - Planning and executing deployments
  - Tracking shipments
  - Distributing material in the theater of operations
  - Managing munitions
- Use capabilities routinely in peacetime operations or exercises/simulations

With today's technology, we should be able to determine our needs and have complete situational awareness of our material: where it is; where it needs to go; how and when it will get there (just like Federal Express). We do not have that capability.

In the Gulf War, the Joint Operations Planning and Execution System (JOPES) failed during the most critical first three weeks. We could not keep track of shipments. Of 40,000 containers sent to the Gulf, 25,000 had to be opened to identify their contents. Containers were stacked up in theater with no effective system for distributing equipment and supplies. We failed at such elementary tasks as having munitions quantities, production rates, capacities, and lead times at our fingertips.

The greatest leverage in improving support to tactical air units is in correcting these long-standing, persistent deficiencies.

The Joint Staff and TRANSCOM have made good starts. But after every war, good starts on fixing these identical problems have faded. Thus, history tells us not to expect the "normal" management system to follow through in correcting these wartime problems.

The Deputy Secretary of Defense should assure that the status, progress, and funding of corrective actions for these chronic deficiencies in wartime logistics capability are reviewed every six months until satisfied that fixes are in place and either used routinely in peacetime operations or exercised regularly.

LOGISTICS AND INDUSTRIAL CAPABILITY - KEY DETERMINANTS OF READINESS

Recommendations - Maintenance Depots:

- Define core requirements
- Compete all other current depot workload
- Consolidate all remaining organic effort by closing excess capacity
- Explore further application of GOCO depots

Considerable savings can be achieved by reducing DoD's organic depot capacity to the minimum "core" necessary to meet readiness and responsiveness requirements and placing the remainder of the depot maintenance work in the private sector. This requires, first, defining minimum core requirements consistently across the military Services and obtaining release from congressional constraints on placing the remainder in the private sector. (Definitions of "core" now vary considerably, but in any case are considerably less than the 60 percent of depot maintenance that must be performed organically by Congressional mandate.)

Second, work not specifically part of the core should be competed among qualified private sector firms. In doing so, DoD should be aware that the motivation for such action is to reduce costs to DoD, not to sustain the industrial base; it is unlikely that the prime contractors whose design, system integration, and manufacturing skills are critical to long-term technical superiority would win competitive maintenance contracts due to their higher indirect costs. If they did, they would be unlikely to perform them with the same management, work force, or facilities used for new aircraft design and manufacture.

Third, the core workload should be allocated (perhaps by competition among government depots) to the minimum number of facilities. The others should be closed. "Indirect" and "G&A" costs of existing organic depots are high (about 40 percent) and insensitive to decreasing workload. They can be best reduced by base consolidation.

Note that we have not endorsed competition between Government and industry as the means for allocating work between them. Rules of competition can never create a truly "level playing field." For example, they cannot take into account the fact that when contractor performed work is complete, labor costs to the Government cease. This is not true in the case of organic depots, where the people performing a specific maintenance effort continue on the payroll, even though the facility may be operating considerably below capacity. Cost overruns also manifext themselves much differently.

Finally, DoD should examine the feasibility of converting one or more of the government aviation-related depots to a government-owned/contractor-operated (GOCO) facility. This could provide the control and responsiveness essential for the core work plus the long-term flexibility in adjusting work force that is so difficult to obtain in a government organization.

LOGISTICS AND INDUSTRIAL CAPABILITY - KEY DETERMINANTS OF READINESS

Recommendations - Industrial Base:

- Lay out the characteristics of DoD's future air forces and consequent industrial support requirements
- Continue communications with industry CEOs on DoD's outlook for necessary downsizing of the industrial base

DoD faces the difficult problem of needing to downsize its industrial base and at the same time maintain critical capabilities to meet future national security needs. Clearly, DoD's future aircraft procurement is insufficient to maintain the more than a dozen plants now capable of fabricating military aircraft. The costs of excess capacity are enormous, even with today's workload. Overhead costs total more than 50 percent of current military aircraft sales. Thus, the number of plants in operation - as distinct from the number of firms - needs to be reduced. (For example, Lockheed's purchase of General Dynamics, Fort Worth, eliminated one competitor, but has not yet reduced excess capacity).

At the same time, low observable material design and manufacturing, as well as the use of composite materials for greater high stress structural application, must continue to be developed and improved. The subsystem vendor base also must be examined carefully to ensure that critical capabilities are retained, such as RF and IR sensors, navigation and guidance equipment, and munitions and their sensors.

The Air Force and Navy have benefited from decades of fighter engine competitions between Pratt & Whitney and General Electric. If technical demonstrations are to be the hallmark of a continuing DoD advancement in high technology, these critical design teams will have to be paired with sufficient manufacturing skills to produce prototype or preproduction aircraft to verify the achievement of producibility and cost goals, not just performance. Clearly, an examination should be made to provide minimum and maximum capabilities at all industrial tiers down through the lowest vendors and suppliers.

Thus, DoD should lay out for industry leaders the details of DoD's aeronautical programs/force plans (and related weapons and C3I) for the next ten years so industry will have the full, factual picture of the magnitude and nature of the decline in defense development and procurement plans. Concurrently, it should determine the characteristics of the air forces that the nation will need ten to twenty years from now and decide the magnitude of the technology and acquisition programs required to maintain the desired capabilities. Finally, it should conduct periodic roundtable discussions with industry CEOs to assess the status and impediments to industry's efforts to reduce capacity.

LOGISTICS AND INDUSTRIAL CAPABILITY - KEY DETERMINANTS OF READINESS

Recommendations - Aircraft Field Maintenance:

- Common Support
  - Establish policy to use common families of automated test equipment
  - Commit R&D resources to continued modernization of common families of test equipment
  - Include common test modules and testing technology in the Joint Advanced Strike Technology Program
- Integrated Weapon System Diagnostics/Prognostics
  - Establish technology development program to focus powers of telecommunications, expert systems, and automation on aircraft troubleshooting
  - Explore technologies for predicting imminent component failures

Common Support:

It is increasingly clear that specialization of test equipment, test manuals, training, etc., is no longer necessary nor affordable. Opportunity exists to create support systems that serve a variety of aircraft, thus reducing acquisition and support costs, enabling simplification and consolidation of support organizations, and facilitating cross-Service support when necessary.

The most immediate payoff appears to be in the automated test equipment (ATE) used for testing avionics. In the last decade, DoD has invested over $35B in such equipment. Developing a standard family of ATE costs about the same as developing peculiar ATE but would then permit large buys of the common equipment. Procurement of standard ATE could save DoD billions of dollars.

DoD should establish as policy the use of common families of ATE, commit sufficient R&D resources to improve reliability and deployability and meet new technology needs, and include ATE in the Joint Advanced Strike Technology Program.

Integrated Weapon System Diagnostics/Prognostics:

Although avionics reliability is improving, troubleshooting remains difficult. For example, 20-30 percent error rates in identifying faulty components are common. False-alarm rates of built-in-test equipment on aircraft run 25-40 percent. These troubleshooting problems ripple through the entire logistics system, creating maintenance workloads at bases and depots and increasing spares requirements.

New technologies offer promise for improving troubleshooting. They include, for example, digital maintenance aids (substitutes for today's technical manuals) that interface with the aircraft's on-board system and lead the technician through the most efficient troubleshooting path and telecommunications systems that can link the flight line technician to base or depot databases or experts.

DoD should establish a technology development program to bring the full powers of telecommunications, expert systems, and automation to aircraft troubleshooting. It also should explore, through R&D and demonstrations, the feasibility and value of predicting imminent failures (sometimes termed "prognostics").

EXERCISE OUR OPERATIONAL CAPABILITY

Problem:

- During peacetime, we do not realistically exercise important elements of the joint force capability due to cost, preparation time, and required facilities
  - Operational exercises incorporating live forces, simulators, and computer wargames can help integrate and evaluate:
    - -- Training
    - -- Doctrine and tactics
    - -- Force configuration
    - -- Logistics

Recommend:

- Increase involvement of senior warfighters in guiding the development of an exercise environment
- Conduct comprehensive exercises, including simulations, of joint forces air/land/sea operations, including force deployments

In Desert Storm we deployed individual combat units in a high state of readiness, but it took months to bring the joint operational force to an acceptable state of readiness. It is unlikely that we will again enjoy the twin advantages of a massive joint exercise area for the deployed forces and ample time to correct the deficiencies. Unfortunately, many of the joint arrangements developed in Desert Shield/Desert Storm were ad hoc and short lived after the conflict.

If, as is likely, future contingencies allow us less time and space to prepare the joint force, realistic exercises during peacetime are the means to assure that the total Tactical Air Warfare System is ready and capable.

We have discussed the potential of advanced distributed simulation to leverage field training and exercise opportunities, to practice logistics support that cannot be adequately tested in the field, short of actual deployment, on a scale that cannot be accommodated on live training ranges.

We have and must exploit the technology to build an exercise environment that will enable us to realistically practice war and that will serve all the purposes shown here. One of last summer's DSB studies focused on that requirement and provided some very specific recommendations. Many are now being implemented, but fruition will require persistent attention.

It is particularly important that the prospective users of this environment - the operational commanders - be heavily involved in guiding its development so that it will support their war readiness needs.

TACTICAL WARFARE SYSTEMS INFORMATION ARCHITECTURE

Problem:
- DoD lacks a comprehensive Tactical Warfare Systems Information Architecture

DoD lacks a comprehensive Tactical Warfare Systems Information Architecture, thereby limiting our Tactical Air Warfare effectiveness. This architecture should be embedded in an overall DoD Information Architecture.

In addition to improving our current ways of conducting air warfare - which are based on information superiority - a comprehensive Tactical Warfare Systems Information Architecture would provide better and more flexible ways of distributing information, and would permit trading off the assignment of functions. For example, if precise targeting information were to be transmitted to a weapons-carrying platform, that platform would not need expensive sensors to rederive that information.

The principal impediments to enjoying these benefits are not technological, but derive from the lack of an overall game plan. Because there has been no effective development and management of a Tactical Warfare Systems Information Architecture, today's systems are largely independently procured. No provision was made, for example, to connect JSTARS data in near real time to Navy or Air Force or Army platforms and weapon systems. Similarly, the three Services, despairing of the likelihood of the intelligence dissemination system sufficiently respecting tactical timelines, developed their own systems.

The result is that each community gathers information redundantly. When inter-connections are needed, they are made in an ad hoc manner, often at the last minute. Opportunities for balanced investment and tradeoffs among warfighting components are thereby lost.

TACTICAL WARFARE SYSTEMS INFORMATION ARCHITECTURE

<u>Information distribution to shooters can be the next silver bullet:</u>

- Benefits:
  - Improves targeting
  - Improves survivability (situational awareness)
  - Improves command and control reconfigurability for differing conflicts
  - Addresses combat identification
  - Permits tradeoffs
- Consequences of no overall game plan are:
  - Unnecessary costs and limited performance gains
- Each community gathers information redundantly
- Ad hoc connections between stovepipes
- Opportunities lost for balanced investment in weapons, avionics, and sensor systems

We believe that our next silver bullet can be improved information distribution to shooters. Relatively small investments in information distribution appear to have greater leverage than similar investments in platforms, weapons, or on-board sensors.

The chart shows the five expected benefits. In addition to improving our current ways of conducting air warfare - which are based on information superiority - better and more flexible ways of distributing information enable trading off the assignment of functions to platforms. For example, if precise targeting information can be transmitted to a weapons-carrying platform, that platform will not need expensive sensors to rederive that information.

The principal impediments to enjoying these benefits are not technological, but derive from the lack of an overall game plan. Each community despairs of receiving timely information from another community, and develops its own stovepipe systems. The necessary interconnections are made at the last minute, and the opportunities for system trades are lost.

TACTICAL WARFARE SYSTEMS INFORMATION ARCHITECTURE

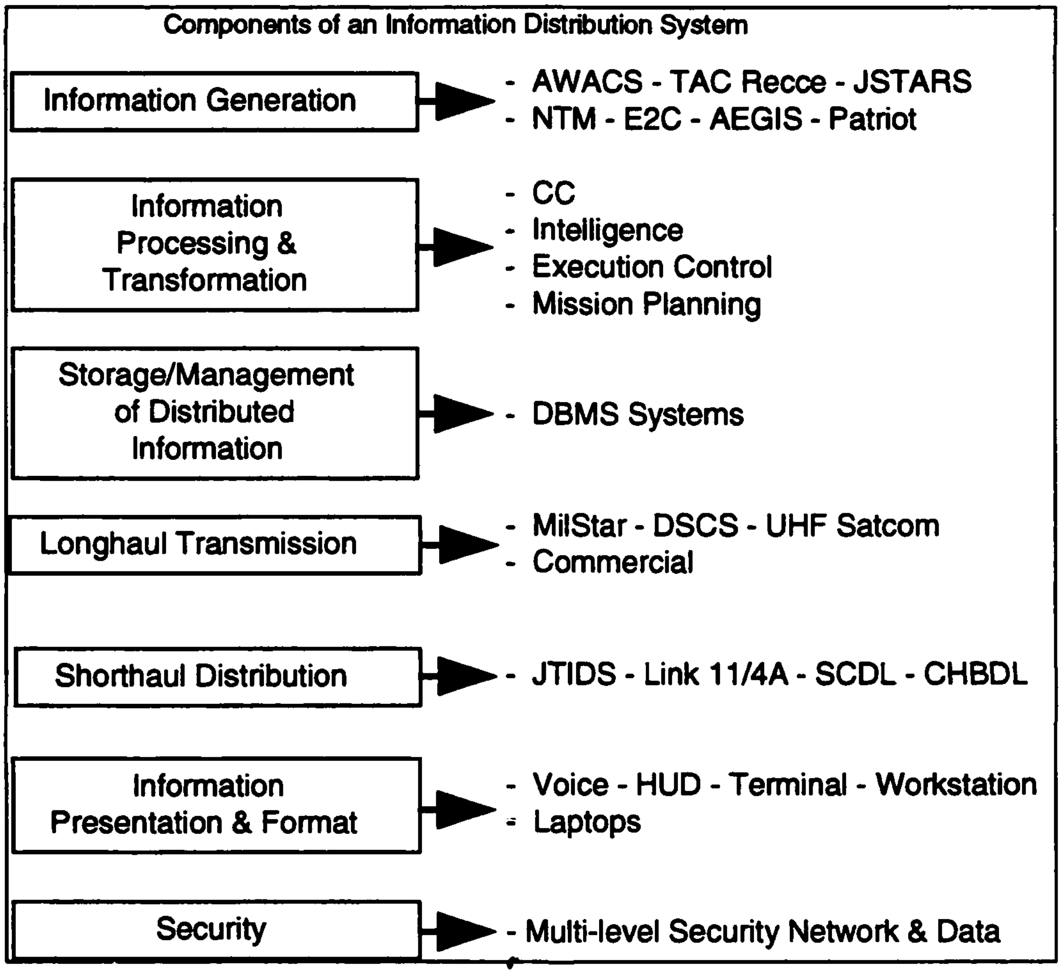
What is an Architecture?

- An information architecture
  - Includes data formats, protocols, message standards, interfaces, etc.
  - Enables open systems - permits individually developed subsystems to interoperate
  - Spans a designated user/server community
  - Provides flexibility in who gets what, when, where, and why
- A communications architecture is not an information architecture
- An information architecture is designed to support the warfighters' information needs

An information architecture is a coherent structure of data formats, protocols, interfaces, and other standards that guides the design and implementation of information subsystems and applications. Adherence to this architecture allows these subsystems and applications to be conceived and developed independently but function as parts of an integrated, open system that serves a wide variety of user needs.

Tactical Air Warfare comprises many communities and is dependent on information architectures of these and external communities. Examples are: Services, Intelligence, Weapons, and Command and Control (e.g., Mission Planning, Tactical Data Links). A TACAIR Warfare Information Architecture will include a Communications Architecture.

DoD TACTICAL INFORMATION ARCHITECTURE COMPONENTS OF AN INFORMATION DISTRIBUTION SYSTEM



An information distribution system consists of numerous functional elements with corresponding system components for carrying out the functions. Today's military information distribution system has been gradually built over many years, with a high sunk cost. To convert this system to one that has the ability to handle more data and confidently distribute data while assuring quality and timeliness will require an evolutionary process, conducted within a standard architectural framework. This framework must be designed to allow the military to take advantage of the commercial subsystem advances in each of the functional areas shown on this chart, while carefully managing the costs of transitioning old systems to the new architecture, and interfacing old and new systems so that they interoperate.

TACTICAL WARFARE SYSTEMS INFORMATION ARCHITECTURE

What's New?:

- Commercial Telecommunications
  - High bandwidth
  - Global cellular
  - Private networks
- Commercial Data Management Systems for managing data sharing with data concurrency
  - Distributed electronic financial transactions
  - Truck/rail shipment tracking
- Widely used commercial software standards
  - Local area networking
  - Display generation
  - File transfer
  - Query languages
  - Network protocol
- Processes for evolving commercial standards
  - IEEE, ANSI, ISO, OSF
- Low cost, integrated commercial products and systems
  - Display technology (flat panels, HDTV)
  - Automotive "avionics" (engine control, navigation)

DoD should use commercial technology and products when implementing a Tactical Warfare Systems Information Architecture.

Commercial industry has moved rapidly within the last 5-10 years to introduce a broad array of computer hardware, high-bandwidth communications products and protocols, distributed database structures, standard user interfaces, application development tools, and object-oriented software tools. A state-of-the-art Tactical Air Warfare Systems Information Architecture would incorporate many of these features.

The key advantages offered by commercial products lie in the areas of cost, availability, and technology insertion. DoD could avoid nonrecurring costs in development and upgrade, as well as recurring costs in maintenance and testing since commercial interests would already incur these as part of a market-driven investment. Other advantages in acquisition cost accrue through the existence of a large user base. Finally, the commercial market, reacting to competitive pressures, will introduce advanced technology expeditiously.

TACTICAL WARFARE SYSTEMS INFORMATION ARCHITECTURE

DoD Information Technology R&D Strategy:

- Understand present and likely future commercial capabilities and match to evolving needs
- Give priority to the special set of information technologies stressed by military applications
  - Data and transmission availability, integrity, and security
  - Application-specific data compression
  - Searches through massive unstructured data
  - EMI suppression related to commercial and military systems
  - Data links to mobile platforms
- Participate with the commercial sector in mutually required information technologies
  - System management tools for:
    - large heterogeneous distributed commercial systems
    - distributed mixed military/commercial systems
  - Network vulnerabilities
  - Special human-machine interfaces and data visualization
  - Object-oriented software technologies

Although the use of commercial technology and products by DoD in implementing a Tactical Air Warfare Information Architecture offers strong and distinct advantages over a purely Department development approach, it must be recognized that there may be a downside to the extensive use of commercial products in military systems. Consequently, a DoD Information Technology R&D Strategy is necessary.

DoD's R&D strategy in this area should be to use its limited resources to address the customization of commercial products to its needs.

R&D in support of DoD information technology must give priority to the special set of information technologies that are stressed by military applications. Generally, it can be expected that a lower level of data and network security and survivability will be achievable with commercial technology. Identical commercial equipment will likely be as available to potential adversaries as to U.S. forces, allowing knowledge of selected applications approaches as a minimum. Special efforts would be required to protect and validate software from viruses and "Trojan Horses."

DoD does not drive the commercial market. Therefore, to assure that its needs will be met, DoD must participate with the commercial sector in the development of mutually required technologies and standards. For example, the DoD strategy should encourage industry to recognize that with modest changes, the development of system management tools for large heterogeneous distributed commercial systems will also support distributed mixed military/commercial systems. For those situations where the products on the civilian market do not recognize network vulnerability, DoD should use its R&D resources to address the problem. Finally, DoD must use its R&D resources to address its special human-machine interface and data visualization requirements that are not otherwise addressed by the commercial sector.

TACTICAL WARFARE SYSTEMS INFORMATION ARCHITECTURE

Recommendations:

- Exploit the commercial market to control costs and to stay modern
- Participate in, and influence when possible, evolution of commercial standards
- Establish an early standard architecture now to get things moving - it will change no matter how long we take
- Transition old systems on an as-appropriate basis; can be very expensive
  - Build custom translators as gap fillers when necessary
- Build new systems in conformance with the goal architecture
- Involve end users in a substantial manner so information architecture can follow evolving warfare system architecture

We believe that the DoD must exploit the commercial market to control costs and to stay modern.

The end users must play a significant role in the processes of establishing the architecture to assure necessary support of military operations.

Most urgently, a standard architecture, consistent with an overall DoD Information Architecture, is needed to get things moving. Things will change no matter how long DoD takes to do the job. The longer it takes the more things will change.

A major problem will be the transition of existing or legacy systems. This must be done carefully. If improper decisions are made, the transition process can become very expensive.

It may be necessary to build custom translators as gap-fillers. New systems will, of course, be built in conformance with the goal architecture.

To do this DoD must, among other things, participate in the process that results in the setting of commercial standards and requirements so that, to the extent possible, the needs of DoD can be accommodated.

DOD TACTICAL INFORMATION ARCHITECTURE

Recommended Key Roles in Implementation:

- CJCS sets expectations/establishes requirements for key components of the Tactical Warfare Information Architecture
  - Establishes a warfighter-focused organization with technical support
    - -- Reengineers Military Operations to take advantage of information
    - -- Harmonizes doctrine and tactics with existing and emerging systems
    - -- Validates through simulations and exercises
    - -- Experiments with commercial components
- ASD(C3I), with Service participation, initiates and oversees design and plan of the end-to-end network for dissemination of Tactical Warfare Systems Information Architecture
  - Enforces architectural compliance and commercial utilization
  - Provides tools for implementation, test, and system management
  - Uses acquisition reform techniques
  - Analyzes costs to transition existing systems
  - Funds existing system modifications as required

Silver Bullet? It's up to us!

We recommend the senior leadership of the warfighter and acquisition communities start work immediately on a Tactical Warfare Systems Information Architecture consistent with an overall DoD Information Architecture.

The JCS should establish a warfighter-based organization, with appropriate technical support, to define the architecture in accordance with emerging operational concepts. A major part of this organization's role is to re-engineer military processes to take advantage of information and to validate these changes through simulations and exercises. This effort should afford appropriate consideration of old DoD information systems and also the integration of commercial technology and products.

ASD(C3I) should assure that Service developments of both new systems and transition of old systems are performed in accordance with this architecture.

ASD(C3I) should design and plan the end-to-end network for distributing Tactical Air Warfare information. The ASD(C3I) must also oversee the data processing activities associated with the Tactical Warfare Systems Information Architecture. This should not be done as a "grand design" type of effort, but should be managed through the use of standards, and by evolutionary acquisition.

ASD(C3I) should provide implementation tools, define test and system management criteria, and provide appropriate funds to achieve necessary modifications to existing systems. The Services should be responsible for implementing the architecture under ASD(C3I) oversight.

Architectures themselves do not necessarily lead to systems that meet performance objectives. Such systems are only built with strong and constant involvement, at every level, by the Operational community. The JCS and CINCs should validate the architecture through simulations, experiments, and operational exercises. This type of development has been demonstrated recently in the combined Air Force and Navy work on the JFACC in the exercises Tandem Thrust 93 and Ocean Venture 93.

CAPABILITY TRADE-OFFS

Problem:

- Tradeoffs are rarely conducted between different categories of weapons, systems, and platforms
  - No prevailing practice exists in DoD to strike an appropriate balance among different ways to perform same function, e.g.:
    - -- Stand-off weapons and/or penetrating platforms
    - -- Missiles and/or aircraft
    - -- Tankers and/or fighter fuel capacity
  - Narrow look at systems leads to sub-optimization
  - Modelling and simulation technology available

Recommend:

- Establish cross-category trade study process to achieve greatest Air Warfare effectiveness
- Conduct under OSD auspices with Warfighter participation

Our Tactical Air Warfare assets generally permit us to do the same job in many different ways.

- Examples are: Standoff weapons and/or deep stealth platforms; platform range-payload and/or tanker use to enhance range; air interdiction and/or surface-to-surface missiles, etc.
- Although we attempt to optimize each of our individual system designs, we do a poor job of tradeoff studies among different categories of weapon systems and platforms to do the same job
- The technology for making credible trades is available

We strongly recommend that DoD mandate a cross-category trade study process, not only for systems in acquisition, but also for modernization and resetting of force levels for systems in the inventory. This should be an OSD function with Warfighter participation.

RECOMMENDATIONS

TACTICAL AIR WARFARE SUMMER STUDY RECOMMENDATIONS

- EQUIP THE FORCE:
  - Develop wide-area surveillance and targeting system that integrates and fuses multi-source data
  - Exploit UAV systems' potential now
  - Equip more aircraft for targeting and delivery of PGMs
  - Accelerate PGM development and procurements
  - Ensure that GPS has adequate protection against jamming
  - Increase priority of improving air-to-air missiles
  - Maintain vigorous CLO hedge program
  - Continue ASTOVL technology effort
  - Focus aircraft commonality on common engines, avionics, weapons, and support
- LOGISTICS:
  - Fix deficiencies in wartime logistics capabilities for planning deployments, tracking shipments, distributing material, managing munitions, and exercise the system
  - Eliminate excess industrial capacity
  - Develop common aircraft support systems and improve automated diagnostic/ prognostics
- EXERCISE OUR OPERATIONAL CAPABILITY:
  - Involve operational commanders in development of new exercise environment that uses distributed, connected live forces and simulation to practice war
- TACTICAL WARFARE SYSTEMS INFORMATION ARCHITECTURE:
  - Establish standards for information architecture now
  - Develop end-to-end plan to implement architecture
  - Exploit commercial standards, products, and practices
- CAPABILITY TRADEOFFS:
  - Require cross-category tradeoff evaluations

This chart reiterates our recommendations in summary form. <u>Note that substantial and important near-term gains in our tactical air warfare capabilities do not require new aircraft programs to be achieved</u>. Such gains can be achieved by <u>equipping our current force</u> and improving the surveillance and targeting, information distribution, and logistics support systems, making those forces much more effective. We must also exercise the resulting operational systems in a realistic environment.

The development of an effective end-to-end, wide-area surveillance and targeting system for both air-to-air and air-to-surface targets is essential. These systems should focus around AWACS and JSTARS, respectively, and include rapid dissemination of multi-source surveillance and targeting data to all elements of the force structure. This ultimate capability will require improvements and integration of our current surveillance and targeting systems and the development of a tactical warfare systems information architecture for effective and timely distribution of the required data. We also believe that UAV systems should be explored more aggressively. These systems offer the potential for operations over hostile territory with reduced vulnerability and risk.

It is critical to our war-fighting capabilities to equip the elements of our tactical air force structure with PGMs and the necessary targeting and delivery systems. To accomplish this, we must increase the acquisition rate and total buys for PGMs and their targeting pods. More aircraft must be equipped with the capability to effectively deliver PGMs under all operational conditions, particularly when confronted with jamming of GPS. We must strive to achieve a stand-off all-weather PGM capability on a large percentage of our tactical aircraft. Most importantly, moving and mobile targets must be addressed in the detection-to-destruction target engagement cycle through a combination of off-board and on-board sensors and seeker capabilities in area surveillance systems, delivery platforms, and weapons.

It is important to note that there is substantial payoff for PGMs in that they require fewer sorties to achieve target destruction. In addition to aircrew lives and aircraft saved, cost savings result not only from less munitions tonnage that needs to be delivered to the target, but also less fuel burned for the platforms required to go on the mission, and for the supporting aircraft that are also required. This payoff will have significant impact on the logistics system needed to supply particular scenarios.

It is critical to fix deficiencies in our wartime logistics capability. Logistics is a key to readiness and we must reduce excess industrial capacity and exercise our logistics capabilities under realistic conditions during peacetime.

Our overall Tactical Air Warfare capability depends on effective utilization of aircraft, weapons, off-board sensors, information distribution, and logistics systems. We must have the capability to evaluate tradeoffs between different combinations of these systems. The capability for effective cross-category trade studies should be established.

APPENDIX A
TERMS OF REFERENCE

THE UNDER SECRETARY OF DEFENSE
WASHINGTON, DC 20301

ACQUISITION

APR 22 1993

MEMORANDUM FOR CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Terms of Reference--Defense Science Board Summer Study Task Force on Tactical Air Warfare

You are requested to form a Defense Science Board Summer Study (DSB) Task Force to review the nation's acquisition options for tactical air warfare over the next 10 to 20 years as force structure is drawn down. The DSB should then recommend promising concepts and technologies to pursue that may have high leverage cost and effectiveness against forseeable threats. The scope of your effort should include all warfare elements to include new or substantially upgraded combat and direct combat support aircraft for tactical forces, avionics, weapons and system integration requirements, operational concepts and plans; target and information requirements; communications; command and control interfaces; and air support requirements to include logistics, and support (tankers). An interim briefing report is requested by 20 August with a final report to be submitted in the November/December '93 timeframe.

The DSB recommendations should address the following questions

- What concepts should be pursued to increase the effectiveness of the resources dedicated to air warfare.
- Are currently planned efforts to operationally integrate tactical warfare assets adequate? If not, what should receive increased emphasis?
- What are the key leveraging technologies today that bear on the effectiveness of tactical air missions?
- Are these technologies being adequately exploited to reduce the cost of aircraft, or at least to mitigate cost growth, as well as to enhance performance?
- What technology areas need increased R&D attention?
- What is the proper balance among weapons, sensors, and aircraft performance?

- Is a Common Tactical Aircraft (CTA) feasible from both the operational and economical standpoint? Do current factors (eg, force downsizing and reduced procurements) make use of common and multi-mission aircraft a preferred approach?

- What is the most cost-effective approach to tactical support missions such as reconnaissance, electronic countermeasures and early warning?

- Are the requisite analytic tools and processes and simulation facilities available to the government to get answers to the foregoing questions and how can they best be employed to make objective trade-off decisions?

- What are the implications of the recommendations with respect to industrial base and world competitiveness?

The ~~Under Secretary of Defense for Acquisition and the~~ Director, Tactical Systems will sponsor and fund this study. Dr. John S. Foster and Dr. Alexander Flax will serve as Co-Chairmen. The office of the Director, Tactical Systems will provide the necessary funding and support contractor arrangements. The Executive Secretary will be Ms. Theresa Atkins and Commander John Dever will be the Defense Science Board Secretariat representative. It is not anticipated that this task force will need to go into any "particular matters" within the meaning of Section 208 of Title 18, U.S. Code, nor will it cause any member to be placed in the position of acting as a procurement official.

John

John M. Deutch

APPENDIX B
TASK FORCE MEMBERS AND GOVERNMENT ADVISORS

Tactical Air Warfare Task Force Members and Government Advisors

Members

Dr. Alexander H. Flax, Co-chairman
Dr. John S. Foster, Jr., Co-chairman

Op Concepts/Force Config Panel

Dr. Werner J. A. Dahm
* Mr. Robert R. Everett
Dr. George H. Heilmeier
ADM Wesley L. McDonald, USN (Ret)
MajGen Jasper A. Welch Jr, USAF (Ret)
* Gen Larry D. Welch, USAF (Ret)

C3I/Mission Planning

Dr. John A. Armstrong
* Dr. Alan Berman
* Dr. Barry M. Horowitz
Mr. Robert F. Nesbit
Dr. George A. Paulikas
Mr. H. Greg Tornatore
Dr. Bruce Wald

Op, Industrial & Logistics Panel

* Mr. Norman E. Betaque
* Gen Russell Dougherty, USAF (Ret)
ADM Isaac C. Kidd, Jr., USN (Ret)
Mr. Sol Love
Mr. Milton A. Margolis
Gen Lawrence A. Skantze, USAF (Ret)

Target Engage Sys/Weapons Panel

* Mr. Donald N. Fredericksen
Mr. Everett D. Greinke
Mr. David R. Heebner
* Dr. Dennis P. Murray
Mr. Robert E. O'Donohue
Mr. Vince Vitto

Aircraft Systems Panel

RADM Robert Gormley, USN (Ret)
* Dr. David E. Mann
Mr. Robert A. Moore
* Mr. Robert N.Parker
LtGen Philip D. Shutler, USMC (Ret)
ADM William N. Small, USN (Ret)
Mr. John J. Welch

Executive Secretary

Ms. Theresa B. Atkins

DSB Liaison/Military Assistant

CDR Robert C. Hardee, USN

* Panel Co-chairman

Government Advisors

BG Ronald E. Adams, USA
CAPT H. Douglas Connell, USN
LtCol Robert Corrie, USAF
RADM John J. Donegan, USN
Col Brian Dugle, USAF
RADM Bill Fallon, USN
CAPT Jim Flaherty, USN
COL Colbert T. Gautreaux, USA
CAPT Tom Hancock, USN
MajGen Larry Henry, USAF
Col Richard Herrington, USMC
Mr. Pete Hoag
BrigGen Ray Huot, USAF
CAPT Terry Jobe, USN
COL Sam Kindred, USA
BrigGen George Muellner, USAF
MajGen Dick Myers, USAF
Col Doug Pearson, USAF
CAPT Howard Petrea, USN
LtCol Art Rooney, USAF
Mr. Robert Thompson
CAPT Eric Vanderpoel, USN

APPENDIX C

REPORT OF THE DEFENSE SCIENCE BOARD TASK FORCE ON AIRCRAFT ASSESSMENT

REPORT OF THE DEFENSE SCIENCE BOARD TASK FORCE ON AIRCRAFT ASSESSMENT

FEBRUARY 1993

CONTENTS

TABLES

INTRODUCTION

Purpose

The Defense Science Board Task Force on Aircraft Assessment[1] was convened to respond to direction received from Congress in the National Defense Authorization Act for Fiscal Year 1993, (Public Law 102-484). The Authorization Act requested that the Defense Science Board address two issues that are related to the DoD Tactical Aviation Modernization Program. The two issues pertain to (1) potential common aircraft/avionics for use by the Navy and Air Force for parallel missions, and (2) technical risk assessments for the F-22, F/A-18E/F, and A/F-X aircraft. The terms of reference (TOR) for the Task Force from USD(A)/DDR&E expanded the issues to include consideration of the desirability of prototyping the F/A-18E/F and A/F-X aircraft.[2] The four issues the Task Force addressed are:

Issue 1: Assess the technical risks associated with the F-22, F/A-18E/F, and A/F-X.

Issue 2: Assess the advantages and disadvantages of prototyping the F/A-18E/F.

Issue 3: Assess the advantages and disadvantages of competitively prototyping the A/F-X.

Issue 4: Assess the ways that current aircraft, upgrades to current aircraft, and new design aircraft can be modified or otherwise adapted so that a single aircraft type can be used by both the Air Force and the Navy in parallel missions.

Task Force Approach

The Task Force first met on January 21; OSD requested the report be provided on February 25. During this time the Task Force met seven times. Briefings and information were received from the military services and OSD, and visits made to Lockheed Aircraft and McDonnell Aircraft to receive further briefings and information on the F-22 and F/A-18E/F programs.[3] The members also made use of other available reports.[4]

Issues 1, 2, and 3 are of more immediate concern. They are relevant to three specific programs, the F-22, F/A-18E/F, and A/F-X. Issue 4 is more general and was addressed in the context of longer-term trends in tactical aviation missions and force structure.

Considerable uncertainties exist in future aircraft acquisition planning. Radical changes in the international scene, and resulting reappraisals of strategy, mission, and force levels are under way. Because studies being conducted on roles and missions and on the affordability of combat aircraft forces had not been completed at the time of these assessments, the probable types and numbers of combat aircraft to be acquired over the next two decades could not adequately be factored into the Task Force's work.

Program Descriptions

F-22 Program

The mission of the F-22 aircraft is theater air superiority. It is an essentially new aircraft that incorporates multiple advanced features, including low-observable characteristics in a highly maneuverable supersonic aircraft, supersonic cruise capability, two-dimensional vectoring engine

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1 The Task Force members are listed in Appendix A.

2 The congressional language is in Appendix B and the terms of reference are in Appendix C.

3 The Task Force schedule is presented in Appendix D.

4 Those reports are listed in Appendix E.

nozzles, software-intensive integrated avionics, and an extensive use of composite and low-observable materials. The F-22 has been in Engineering and Manufacturing Development (E&MD) since August 1991. The advanced nature of the F-22 should be put into the context of the risk reduction achieved prior to E&MD start. An extensive Demonstration and Validation (Dem/Val) program was performed with competitive flying prototypes of the airframe/engine configurations and avionics flying testbeds including brass board components.

F/A-18 Program

The F/A-18E/F is a multi-role fighter/attack aircraft for the Navy. It has been in E&MD since May 1992. In contrast to the F-22, the F/A-18E/F is an evolutionary development based on the F/A-18C/D. The F/A-18E/F airframe is a scaled-up version of the F/A-18C/D with a new engine derived from the A-12 program and other recent engines. The avionics are planned to be almost a direct carry-over from the F/A-18C/D. Important performance goals are increases of 30 percent mission radius and 60 percent bring-back weight, and enhanced survivability including reduced signatures, relative to the F/A-18C/D.

A/F-X Program

The A/F-X is being designed as a multi-role attack/fighter aircraft for the Navy and a deep interdiction aircraft for the Air Force in response to a joint operational requirements document. The A/F-X is expected to have a new airframe configuration that incorporates advanced low-observable and associated materials technologies. The engine will be from a new generation of engines exemplified by significant improvements in thrust-to-weight ratio and operation at high levels of turbine inlet temperature. The aircraft's avionics suite is expected to draw heavily on the integrated avionics from the F-22 program. The A/F-X is being prepared to enter Dem/Val.

SUMMARY

Issue 1 Findings: Technical Risk Assessments

The Task Force reviewed the technical risks associated with the three tactical aircraft programs. Because technical risk cannot be entirely separated from schedule and cost risks, the Task Force also examined those aspects of the programs. Sources of cost risk that all programs are currently exposed to are the growth in overhead costs as a consequence of decreases in the business bases of the prime contractors and suppliers, reductions in planned production rates, and disruption of planned funding profiles for programs.

Both the F-22 and F/A-18E/F programs could become budget-driven rather than event-driven and may therefore encounter further difficulties. Funding of risk reduction efforts in E&MD must be maintained for the F-22 and F/A-18E/F aircraft programs if program milestones and technical risk reductions are to be achieved without undue increases in overall program risk. A more detailed discussion of specific risk areas is included in the Discussion section.

F-22 Program

The Task Force views the area of highest technical risk in the F-22 program as the integrated avionics and its associated integration software. Other risk areas include low-observable materials and structures, engine durability, and weight and drag management. The Task Force believes that the critical risk areas have been clearly identified, are being addressed to the extent commensurate with their importance and are being adequately managed. Particular note is taken of the extensive avionics flying testbed program. The compounding of the technical challenges, potential adverse economic factors, and cost uncertainties, as described in the first paragraph of these findings, could pose serious risk to the program. The F-22 program was recently rescheduled for funding and other reasons. The first flight date was delayed 11 months. Further

schedule delays at this time due to reduced E&MD funding are unlikely to reduce risks and will increase costs.

F/A-18E/F Program

Risks are seen as relatively low in the F/A-18E/F program due to the evolutionary development nature of the aircraft. Risk areas include weight management, airframe materials, and the new larger engine that is an outgrowth of the A-12 engine. The F414 first-engine-to-test will be in May 1993. Again, the Task Force believes that the critical risk areas have been clearly identified, are being addressed to the extent commensurate with their importance, and are being adequately managed. As is the case with the F-22, the F/A-18E/F first flight has recently been rescheduled, being extended by two months due to lower than planned appropriations. The previous discussion of schedule and cost risk implications of program delays due to funding reductions is equally relevant to the F/A-18E/F program.

A/F-X Program

Because the A/F-X program is still undergoing a design competition before Dem/Val, it is simply too early for the Task Force to make a technical risk assessment of the A/F-X aircraft. The A/F-X mission requirements for both the Navy and Air Force appear to be achievable, and the Navy is managing the program at this time to ensure adequate performance margins, including carrier suitability. Tradeoffs of cost, performance, and other requirements have been important elements of the current phase of the program. Once prototype designs are submitted, a meaningful assessment of the A/F-X aircraft's technical risk can be made. The planned Dem/Val program appears to be structured to accommodate a substantial risk reduction effort.

Issue 2 Findings: Prototyping the F/A-18E/F

The Task Force could not find any basis for prototyping the F/A-18E/F aircraft. The F/A-18E/F is not a high-risk program in terms of concept, design, performance or operational suitability. In many ways the F/A-18C/D can be considered a prototype of the F/A-18E/F. The aerodynamic and structural concepts for the F/A-18E/F are essentially the same as those of the F/A-18C/D. Aerodynamic and other design models and tools used in the F/A-18E/F program have been calibrated and validated using data from earlier F/A-18 flight testing. This has provided information of the kind that would be available from a flying prototype. Technical risks remaining in the program (e.g., weight) can only be confronted in the E&MD program with E&MD-designed hardware including flight-test articles. E&MD flight testing using the first two flight-test articles can provide sufficient information to assess important performance parameters prior to large production funding commitments. The additional costs (in time and money) of disrupting the E&MD program and building additional flying prototypes far outweigh the value of any potential risk reductions.

Issue 3 Findings: Prototyping the A/F-X

Current A/F-X requirements call for a level of design innovation that justifies a flying prototype before the start of E&MD. The A/F-X program is planned to follow an acquisition strategy for competitive prototyping of the aircraft during Dem/Val. If the design competition leading to Dem/Val provides a clear winner, then a single design could be prototyped. Because the A/F-X is likely to employ avionics concepts and common equipment from the F-22 program, avionics prototype testing in a flying testbed may be required only for selected components, systems integration and software.

Issue 4 Findings: Common Aircraft/Avionics Programs

Aircraft used by more than one service can result in lower development, production and support costs. Multi-role aircraft within a service achieve the same ends. The components of an aircraft system (airframe, engine, and avionics) may also be modified to adapt to a new mission or to modernize the system. For example, avionics, which in recent years have on average been modernized within a 10- to 15-year cycle, may account for up to one-third of a fighter/attack aircraft's system acquisition costs. The measures of merit to use in deciding whether to design a new aircraft (or modify an existing aircraft) for multi-role or multi-service applications should be mission effectiveness and life-cycle cost of the force.

Factors that affect these decisions include (1) mission assignments of force elements within the operational force structure, (2) size and composition of forces required to meet national strategies and objectives in the face of anticipated threats, (3) timing and phasing of aircraft programs, and (4) the current trend toward longer operational life of aircraft, including upgrades.

In spite of the potential advantages of common aircraft, each service has had compelling reasons to acquire some aircraft with characteristics primarily designed for its most demanding missions, with minimum compromise for multi-role or multi-service use. Navy aircraft must be carrier-suitable and the requisite structural and aerodynamic features must be part of the design from the beginning. Although these features impose weight, performance, and cost penalties over a similar aircraft designed for land operation only, historically, variations in ship- and land-based versions have led to workable solutions for near-common missions.

The economic dimension to acquisition decisions is enlarged upon in the subsequent discussions. In the future, the greater economic constraints and lower rates and quantities of combat aircraft to be acquired will tend to make the use of common aircraft and/or component subsystems more attractive than it has been in the past, although this may require some compromise in mission capabilities.

Although the A/F-X is still in an early stage of development, the Navy and Air Force are succeeding in arriving at a high degree of compatibility in the aircraft characteristics to meet their respective mission requirements. It is also planned that this aircraft will incorporate avionics having a substantial degree of commonality with the F-22.

The multi-role F/A-18E/F is planned for acquisition by the Navy only. Although geometrically similar in configuration to the F/A-18C/D, the F/A-18E/F has a larger airframe and engine and is linked to the F/A-18C/D mainly by common avionics. The F/A-18E/F could be employed by the Air Force for operation from land bases. However, it is substantially heavier and more costly than the aircraft the Air Force envisions as a replacement for its multi-role fighter/attack aircraft (currently the F-16). A new multi-role fighter/attack aircraft is not expected to be required to become operational for perhaps 20 years. The Air Force, however, has proposed that the Navy join it in examining the possibility of a joint program to acquire such an aircraft, the Multi-Role Fighter (MRF) in this longer time frame.

DISCUSSION

Technical Risk Assessments

The Task Force was asked to assess the technical risks of the F-22, F/A-18E/F, and A/F-X aircraft programs. Technical risk is a subjective assessment regarding the likelihood or probability of not achieving a specific objective by the time established and with the resources provided or requested. It is also usually a relative assessment in that one program can be viewed as lower or higher risk than another. Since it is difficult to completely separate technical risk from schedule and cost risks, the Task Force also considered those aspects of the programs to the extent that they might have significant impact on technical risks. For instance, sources of cost risk that all programs are currently exposed to are the growth in overhead costs as a consequence of decreases in the business bases of the prime contractors and suppliers, reductions in planned production rates, and disruption of planned funding profiles for programs.

The F-22 incorporates revolutionary advances in airframe, low-observable technology, maneuverability, engines, materials, and integrated avionics systems. The F/A-18E/F, on the other hand, is an evolutionary development of a scaled-up F/A-18C/D multi-role fighter/attack aircraft. While the overall airframe structure is almost completely new, the aerodynamic performance is relatively well-understood because of extrapolation from the performance of the F/A-18C/D design. Also, avionics is the same as on the F/A-18C/D, and the F414 engine, although a new design, is derived from earlier engines, primarily the F412 designed for the A-12.

A great deal of risk reduction had already taken place in both the F/A-18E/F and F-22 programs before their respective E&MD starts. The F-22 E&MD was preceded by an extensive Dem/Val program specifically designed to prototype the highest risk technical areas with competitive ground and flying prototypes of the airframes, engines, and avionics (including flying test beds). The F/A-18E/F benefits from the application of F/A-18C/D experience, wind-tunnel testing, and engine component testing. The following subsections contain comments on each program concerning challenges that have been revealed during E&MD. Also noted are the schedule and cost risk impacts of program changes which have affected both developments.

The Task Force believes it is too early to make a technical risk assessment of the A/F-X aircraft because the design concept is not firm. However, it is not too early to comment on the relative technical ambition of the A/F-X program implied by its mission requirements.

F-22 Program

The F-22 E&MD program has experienced difficulties typical of aircraft programs in E&MD. Airframe design refinements have had negative impacts on weight and drag. In particular, "bumps" resulting from the repackaging of internal systems have caused increased drag. However, there is still margin in currently estimated levels of weight and drag to meet the System Operational Requirement Document (SORD) and Approved Program Baseline (APB) performance goals. Lockheed Aircraft has identified areas for additional fuel tankage as a hedge against possible increases in weight, drag and specific fuel consumption (SFC) at mission design points.

The F119 engine began ground testing in December 1992. Difficulties revealed in ground testing included performance shortfalls in the fan and turbine and high stresses in the second fan blade and low-pressure turbine blade. Lower-than-expected fan efficiency presents a risk in meeting subsonic SFC specifications. However, with identified planned improvements for several components, SFC is predicted to surpass specifications. Overall engine weight is below specification, but the nozzle is above its allocation; because of the nozzle's aft location, this may have implications for the aircraft's center of gravity (CG). The new materials technology associated with the nozzle may present durability problems.

The highest technical risk in the F-22 program stems from a new concept in aircraft avionics—a highly integrated avionics functionality expected to reduce pilot workload substantially and provide the pilot with unprecedented situation awareness. During the Dem/Val phase of this program, algorithms for data fusion and software development were examined, and a flying testbed was used to reduce the risk for some elements of the avionics. During E&MD a new computer processor is being designed, considerable software will be written and ground tested, and avionics system and software integration will be accomplished on the flying testbed before integration into the F-22 aircraft. The newness of the concept (compared to the avionics architecture of what is flying now) and the extensiveness of the integration represent a technical risk that warrants continuing aggressive management attention.

Low-observable and other new composite materials present another area of risk, as is the case in most advanced low observable aircraft. The radar radome, which is part of the aircraft's integrated forebody, requires relatively risky materials/manufacturing concepts that deal with the offsetting requirements of radar detection range, aerodynamic performance, and radar cross-section.

The F-22 program was recently rescheduled due to funding shortages. The rescheduling resulted in an 11-month delay in the first flight date (to 59 months from E&MD start, twice as long as average recent experience) and an 18-month delay in the planned Milestone III date. These delays should not be misconstrued as further reducing risks since resource shortages are not allowing known technical risks to be attacked as soon and as aggressively as they could be. An important exception is in the area of software and processing, where the contractor has maintained the original schedule and staffing plans.

Because certain fixed costs are associated with development programs over their duration, the schedule expansion will probably result in increased E&MD program costs. As in other current programs, additional decreases in the business base of F-22 contractors due to the cancellation or extension of other programs would result in additional cost risk; such a decrease could adversely impact overhead burdens on the F-22 program.

F/A-18E/F Program

The F/A-18E/F has experienced typical development difficulties. The most serious technical problem encountered is a shortfall in predicted maneuver performance at high angles of attack. This shortfall was discovered in wind-tunnel testing in June 1992. The problem has been addressed through redesigned fuselage leading edge extensions (LEX) and attendant modification to other affected parts of the aircraft. Unfortunately, a weight penalty of about 250 pounds is associated with the new design; this represents a considerable portion of the 450-pound E&MD (pre-first flight) margin for empty weight. Although avionics software is a low-risk area for the F/A-18E/F program (because most of it is carried over from the F/A-18C/D), software growth of approximately 15 percent has already been experienced in the combined F/A-18C/D and F/A-18E/F effort. Low-observable and other somewhat new composite materials present another area of risk.

Component testing is well underway in the engine program for the F/A-18E/F. The first F414 engine to test is scheduled for May 1993. Testing to date indicates that thrust and SFC performance should be met. One problem that emerged during testing was a shortfall in predicted fracture mechanics life of the stage-one disk. This problem can be addressed through shortened inspection intervals (1,000 flight-hours versus the specification of 2,000 flight-hours) or through design changes with small weight penalties.

The previous discussion of schedule and cost risk implications of program changes for the F-22 is equally relevant to the F/A-18E/F program. The F/A-18E/F's first flight date has only been stretched-out two months so far during E&MD from 42 months to 44 months. Additional program changes due to insufficient funding could increase program risks.

A/F-X Program

Because the A/F-X program is still undergoing a design competition before Dem/Val, it is simply too early for the Task Force to make a technical risk assessment of the A/F-X aircraft. The A/F-X mission requirements for both the Air Force and Navy appear to be reasonable and achievable, and the Navy is managing the program at this time to ensure adequate performance margins, including carrier suitability. Tradeoffs of cost, performance, and other requirements have been important elements of the current phase of the program. Once prototype designs become firm, a meaningful assessment of the A/F-X aircraft's technical risk can be made. However, the planned Dem/Val program including prototype flight tests appears to be structured to accommodate a substantial risk reduction effort.

Summary

The Task Force considers the F-22 to have higher technical risk than the F/A-18E/F. It is the judgment of the Task Force that the F-22's and F-18E/F's critical risk areas have been clearly identified, are being addressed to the extent commensurate with their importance and are being adequately managed. There is a danger that both the F-22 and F/A-18E/F programs may become budget-driven rather than event-driven and may thereby encounter further difficulties. Full funding of E&MD for the F-22 and F/A-18E/F aircraft programs is required if program milestones and technical risk reductions are to be achieved.

Common Aircraft/Avionics

Multiple applications of aircraft/avionics and other major components are fundamentally related to cost-savings or affordability issues but the effect of such a strategy on the effectiveness of the force structure relative to other options must be carefully weighed. Key factors affecting cost-effective choices of aircraft systems include:

- mission assignments of force elements within the operational force structure,
- size and composition of forces required to meet national strategies and objectives in the face of anticipated threats,
- timing and phasing of aircraft programs, and
- the current trend toward longer operational lives of aircraft, including upgrades.

With the radical changes taking place in the international community, and the reappraisals of force levels and compositions in light of these changes, the studies of roles and missions and of affordability of aircraft force structures under way will have a major effect on the types and numbers of aircraft to be acquired over the next several decades.

Common Aircraft and Parallel Missions

The use of common aircraft has two dimensions—the use of common aircraft for parallel missions across military services and the use of common aircraft within a service for multiple missions. Both uses can reduce overall development, production, and support costs. Aircraft may be adapted or designed in several versions from the outset to perform multiple missions within a service or parallel missions across services. The measures of merit to use in deciding whether to design a new aircraft (or modify an existing aircraft) for multi-role or multi-service applications should be mission effectiveness and life-cycle cost of the force.

Critical mission requirements and design considerations can dictate whether a particular aircraft has the potential for other missions within a service or similar missions across services. The services' experience has been that some, but not all missions demand aircraft whose design is strongly focused on a single mission with minimum multi-role compromise. The two most notable examples are theater-level air superiority (dominating airspace over hostile territory and over

friendly territory) and deep strike. In both cases, life-cycle cost must consider outside support required to perform the mission effectively—air refueling, defense suppression, escort, airborne surveillance support, and overhead support. Since both missions must be performed deep in hostile territory, outside support can be difficult and costly to achieve and may result in high attrition in supporting forces.

The specialized aircraft that fulfill the most demanding missions (e.g., theater air-superiority and autonomous deep strike) make up the high end of the force mix. Multi-role and multi-service aircraft have been successfully employed in the less-demanding aspects of both air-to-air and air-to-ground missions; these aircraft constitute the low-end of the force mix. Within their own domains (i.e., air-to-air or air-to-ground), the high-end aircraft could fulfill most of the less-demanding missions. However, because low-end multi-role aircraft have historically cost half as much as high-end aircraft (e.g., F-16 vis-a-vis F-15), they have provided a much more affordable means of providing an adequate force structure.

Modern aircraft designed for the air superiority role have been successfully adapted to the air-to-ground mission to include part of the deep-strike mission. The high thrust-to-weight ratio and low to moderate wing-loading characteristics of an air superiority design provide the ability to carry significant ordnance loads while preserving the maneuvering performance needed to enhance survivability. The avionics suite needed for a modern air superiority aircraft provides flexibility to adapt to air-to-ground demands. Both the Navy and the Air Force adapted the F-4, originally designed as the Navy's primary air warfare aircraft, to an air-to-ground role. However, the reverse is not true: deep strike or attack optimized aircraft cannot be modified to an air superiority/air warfare role.

Similarly, naval aircraft must be designed first and foremost to be suitable for aircraft carrier operations. The requisite structural and aerodynamic features must be part of the design from the beginning. These features impose weight, performance and cost penalties over similar aircraft designed for land operations only. Carrier-suitable Navy aircraft have been successfully used by the Air Force in the middle range of mission demands (the F-4 and A-7 are notable examples), but there are no examples of Air Force aircraft being modified to Navy carrier-suitable missions.

The most unsuccessful common use attempt was the effort to field a truly common, multi-role, multi-service aircraft, the F-111 program, which attempted to span too large a range of disparate missions. In the end, the aircraft was considered unsuitable for both Navy carrier operations and Air Force multi-role operations. After extensive and costly modification, the aircraft became the most capable deep-strike aircraft. In the end, the common, multi-role design became the Air Force's most specialized, single service, single-role aircraft fulfilling what was the original Air Force mission requirement for the F-111A (although it was later modified again to the EF-111).

Another trend of importance has been a significantly extended useful operational life for fighter aircraft. Up to the 1970s, fighter aircraft tended to become obsolete in their primary design mission in five to ten years. In contrast, the F-15 and F-14 have served as the Air Force and Navy primary air superiority/air warfare aircraft for almost twenty years and must continue to serve that role for at least another ten years. The F-22 will then assume that role for the Air Force. The previous plan was for a naval variant, the NATF, designed for carrier operations, with common engines, avionics, and low-observable and airframe technology, to serve the Navy's future high end air superiority needs. The A/F-X is currently planned to complement the F/A-18E/F in the Navy's air warfare missions.

Table 1 presents past, present and future Navy/Marine Corps and Air Force tactical aircraft and possible future options of upgrades and new designs as they relate to missions. In the 1970s there were approximately two dozen aircraft types in this matrix; now there are about one dozen. As the table indicates, possible future options might result in further reductions in type, although such reductions should not be judged on the basis of commonality alone. Compromises are made in mission effectiveness to achieve aircraft/avionics commonality.

Table 1. Aircraft-Mission Match

Mission	1970s	1990s	2020s Modern	2020s Aging
Theater Air Superiority				
Air Force	F-15, F-102, F-104, F-106, F-101B	F-15A/C	F-22	F-15C ?
Battle Group Air Superiority				
Navy/Marine	F-14, F-4, F-8	F-14A/D	F/A-18E/F, A/F-X	F-14 ?
Strike/Attack				
Air Force	F-111, F-100, F-105, A-7, A-10	F-15E, F-117, F-111, A-10	A/F-X	F-15E, F-117
Navy/Marine	A-6, A-4, A-7, AV-8A	A-6, AV-8B	A/F-X	
Multi-Role				
Air Force	F-4	F-16A/C	MRF	F-16C ?
Navy/Marine	F-4	F/A-18A/C	F/A-18E	FA/-18C ?

Equally important with the application of common aircraft, the application of common aircraft components provides opportunities for life-cycle cost savings. Major components (engines, airframes, avionics, and weapons) may be integrated in differing overall system configurations. For tactical fighter/attack aircraft, engine Research, Development, Test and Evaluation (RDT&E) and unit flyaway costs may account for 15–20 percent of total vehicle system cost, with avionics typically accounting for 25–35 percent. Thus, it is possible that up to 50 percent of vehicle system RDT&E and flyaway costs may be based on common component development and production even with differing airframe configurations. There are many examples of successful common component applications, particularly a long history of multiple engine applications going back to the first generation of J33 and J35 turbojets. The TF-30 engine was used in the F-111, A-7 and F-14A. More recently, the F100 engine was used on models of the F-15 and F-16 aircraft, and the F110 engine, on models of the F-16 and F-14 aircraft. Numerous similar examples exist for electronics/avionics equipment.

Possible Common Aircraft/Avionics Options

The cost-effectiveness of using common aircraft/avionics for a specific application will depend upon the degree to which costs savings and other commonality advantages are offset by the disadvantages inherent in commonality.

Program managers, if given the choice between off-the-shelf or new common aircraft equipment will usually make a decision from a program perspective and not the full life-cycle view of the system user or the overall DoD budget impact. It is essential that the technical "price" of using common items be carefully evaluated in relation to the full life-cycle cost savings implications. The ability of common items to ease system integration, reuse software, avoid development duplication, lower production cost, and reduce support cost must be fully weighed against the inefficiencies (lower performance, higher weight, etc.) that may be introduced by using common items. Table 2 lists some advantages and disadvantages of aircraft/avionics commonality.

Table 2. Advantages and Disadvantages of Aircraft/Avionics Commonality

Advantages	Disadvantages
• Decreased development cost and technical risk through reduction in systems, subsystems or components that must be developed • Decreased production costs through economies of scale • Decreased operating and support costs by reduced spares costs and test equipment needs • Reduced avionics software and integration costs and technical risks through use of standard interfaces and protocols provided by common modules and by increased software reuse • R&D technology base funds can be better focused on critical technology issues by the reduction of duplication of systems/subsystems across services	• Aircraft/avionics mission performance, weight, and volume will be less than optimum for a given application • Military application of technology may not advance as rapidly • Administrative burden to achieve an effective common equipment program across weapon platforms and across services may be significant • Some loss of industrial infrastructure may occur with fewer suppliers • Specific problems in design, manufacture, and operation can affect more programs • Cross-service logistic infrastructure requirement may increase costs

The area of avionics needs careful examination with regard to upgrades of existing systems in the future. Electronics technologies can provide a common integrated architecture and allow commonality at the module level while still achieving technology advances in selected modules through pre-planned product improvements. Such a standard architecture has been defined by the Joint Integrated Avionics Working Group (JIAWG). Within-platform avionics commonality is more readily achieved, as exemplified by the wide application of JIAWG common modules within the F-22, because it is generally consistent with the contractor and government program managers' *objectives*. Across-program commonality (such as applying F-22 avionics modules to the A/F-X) is more difficult because it requires coordination across program offices and makes the following program dependent on subsystems and technology that may be viewed as obsolescent and less subject to control by the program manager.

The potential for the cost-effective application of almost identical aircraft and components for a variety of missions and in varying environments depends in large measure on how dissimilar the missions the aircraft is intended to perform are. Also important is the degree of overlap or complementarity of other aircraft types included in the overall force structure in which the specific aircraft is to be included. Major factors influencing costs are the numbers to be produced for each mission category or service environment and the timing and phasing of programs. If small numbers of aircraft are to be produced for each mission or service, then the relative advantage from RDT&E costs in common will offset to a considerable extent the potentially higher unit costs ("technical price" and non-optimized unit cost) of a single aircraft system or component to perform well in multiple missions and multiple environments. Another important factor is the phasing of force modernization across the services and mission areas. Although a new aircraft design may have the potential for application across missions or services, there may be no near-term need for a new aircraft in more than one application.

The Task Force has identified several possible future options for common aircraft in both the high and low ends of the aircraft performance spectrum, for subsystem upgrades to current aircraft, and for new design aircraft, although most of the options do not reflect current requirements or planned acquisitions of this service.

- For Upgrades to Current Aircraft:
  - Navy F/A-18E/F upgraded with modernized avionics for future Air Force multi-role fighter (air superiority and ground attack) for the low end of the force mix.

- Air Force growth F-16 upgraded with modernized avionics for Air Force multi-role fighter for the low end of the force mix.

- For New Aircraft:
  - A/F-X for the Navy and Air Force high end of the force mix to serve as the future ground attack and interdiction aircraft. In its multi-role Navy version it would also serve as the Navy's future air warfare aircraft. The Navy and Air Force are working jointly on this Navy-led program. The A/F-X avionics can be derived from F-22 JIAWG-type avionics.
  - Multi-Role Fighter (MRF) is being considered for the low end of the Air Force tactical air force mix for both air superiority and ground attack. The MRF program is intended to start toward the end of this decade or beginning of the next decade. It could also serve the Navy as a replacement for the F/A-18 if designed from the outset for carrier suitability. (Airframes might differ to a considerable degree but this is not a given, however. Both services could use the same engine and avionics).
  - F-22 upgrade to perform the Air Force high end of the tactical aviation ground attack role (similar to F-15E upgrade from F-15C) and/or F-22 avionics upgrade to perform an electronic combat role.

The current common-use aircraft program, the A/F-X seems reasonably well on track. Although both services seem committed to a common-use design, it is far too early in the program to make judgments about the outcome. Both services will clearly need a follow-on deep strike aircraft to replace the aging A-6 and F-111 and eventually the F-117 and F-15E.

That leaves the possibility of a multi-role common-use design as a follow-on to the F-16 and F/A-18. Again, it is far too early to make judgments about the prospects but past experience gives some indicators of the prerequisites for, and likelihood of success. If, as is likely and prudent, the requirement includes advanced low-observable characteristics, the follow-on would need to be a very significant departure from either aircraft. At the same time, the follow-on needs to be significantly lower in cost (nominally half) than the F-22 or the A/F-X to provide an affordable force. Given that aggregate force mission effectiveness and life-cycle cost are the relevant measures of merit, the development cost savings from common aircraft use may not be sufficient when measured against total force life-cycle cost and mission effectiveness considerations. It is too early to make decisions about commonality and effectiveness tradeoffs, prior to a design competition of competing concepts.

Prototyping

A common definition of a prototype as a representative working model used (1) to reduce technical risks in a new system or subsystem, (2) to answer design questions to some degree, and (3) to provide necessary confidence before moving to the next phase of a system acquisition with better technical, schedule, and cost information and estimates for the system.

Both ground and flight prototype testing in the Dem/Val Phase *reduce* the technical risk of a program, thereby reducing the schedule and cost risks in proceeding to E&MD (and production). Prototyping *does not eliminate* technical, schedule, and cost risk—that is why there is an E&MD. Prototypes cost money and take time—sometimes they are justified and sometimes not, depending on the degree of technical advance sought in a system or subsystem, the nature of the technical risks and the costs of risk reduction at various stages of an E&MD program.

Flying prototypes may fulfill a number of requirements in a development program and provide data in a variety of ways to reduce technical risks, as listed in Table 3.

Table 3. Flying Prototypes Provide Data to Reduce Technical Risk

Characteristic	Flying Aircraft	Engines	Avionics Testbed
Aerodynamic Performance	Substantial	Substantial	N/A
Weight Data	Limited	Limited	Limited
Flight Control Functions	Substantial (FBW)[a]	Substantial (FADEC)[b]	N/A
Avionics Functions	Limited	Limited	Substantial
Engine Performance	Substantial	Substantial	N/A
Signature	Possible/Substantial	Possible/Substantial[c]	Possible
Airframe Integration			
Structure	Some[c]	Some[c]	N/A
System	Some	Some	N/A
Durability	Limited	Limited	Limited
Producibility	Some	Some	Some
Software	Some	Some	Some

[a] FBW stands for fly-by-wire.

[b] FADEC stands for full authority digital engine control.

[c] Limited in recent prototypes.

[d] Boilerplate structure often used.

In some cases, prototypes may demonstrate and validate certain system performance and mission capabilities or indicate their deficiencies early enough to permit design revisions before large expenditures are committed to E&MD. However, the more complete and representative of the final production system the prototypes are to be, the more of the total detailed design and preflight development and integration effort (including extensive ground testing of components) must be completed before prototype construction and the greater the cost incurred. Carried to the limits of completeness and verisimilitude, a prototype can be essentially equivalent to the flight test aircraft in the E&MD program.

Pre-E&MD prototypes in the recent past (the YF-16, YF-17, and YF-22) have not been complete system prototypes but rather have been bare air vehicles. They have served to verify aerodynamic and flight control characteristics, and airframe-engine interactions affecting flight vehicle performance and operation. They did not demonstrate or validate mission avionics and weapons-delivery capabilities, nor, for the most part, did they validate the structural integrity or weight of the final production aircraft since their structures were not completely representative nor was there sufficient intensity and repetition of loading of the airframe to establish long-term durability and fatigue life of the aircraft. Ground tests typically carried out as part of an E&MD program provide the only development tools available for establishing long-term structural integrity of the airframe and durability of the engine before accumulating thousands of hours on operational aircraft. Pre-E&MD prototype vehicles whose aerodynamic configuration and flight control characteristics are very similar to the final aircraft can validate, and may in some cases modify and improve the accuracy of magnitude and distribution of flight loading (steady, vibratory, acoustic, and transient) to which the structure must be designed. Also, aerodynamic interactions of the airframe and engines can be assessed with greater accuracy than provided by wind-tunnel and ground engine test cells. The likelihood that these characteristics will be significantly different in prototype flight test from those derived from engineering analyses, wind-tunnel, and ground test depends on the degree to which airframe and engine depart from prior recent design configuration and operating regime experience.

Prototyping of various systems and subsystems may be considered for reasons other than technical risk reduction. These include permitting preliminary testing or demonstration of

operational utilization and in some cases obtaining technical information needed in development (e.g., qualification testing) earlier and at lower cost than by alternative means. There are also reasons why pre-E&MD flight prototyping may not be desirable, particularly when technical risk is relatively small and time and money is better used in the E&MD program addressing the overall development process. Table 4 summarizes advantages and disadvantages of flight test prototyping.

Table 4. Advantages and Disadvantages of Flight Test Prototyping

Advantages	Disadvantages
• Reduces technical risk in testbed features • Provides better technical, schedule, and cost information and estimates of testbed features • Allows joint ventures and design and management teams to work together early in the program • Can provide data on flight envelope not available from wind-tunnel tests (aerodynamic and engine performance, flight controls, airframe/engine interface).	• Up-front investment can be substantial • Schedule to Initial Operational Capability (IOC) can be longer • Slows momentum of program • Flight data may not significantly alter wind-tunnel and engine ground test characteristics for conventional designs • Final E&MD design may differ substantially • Critical structural and other life-cycle characteristics of aircraft and engine not validated by prototype flight tests

Whether competitive prototypes (which, unless substantial contractor financial participation is forthcoming, are more costly) should be used may be more an issue of acquisition strategy in a particular program than a question of technical risk reduction. On the other hand, it may be both necessary and desirable to pursue evaluation of competitive prototypes as an important element of an acquisition program, particularly if they embody significant departures from recent design experience and also differ substantially from one another. Table 5 summarizes advantages and disadvantages of competitive prototyping of flight vehicles.

Table 5. Advantages and Disadvantages of Competitive Flight Prototyping

Advantages	Disadvantages
• Expands the choices for the government; could result in better product. (best of two versus best of one) • Product could be less expensive • Contributes to industrial base maintenance • Encourages "best efforts"[a] by contractor teams • Increases chances of solving key problems.	• Increases development cost • Increases length of schedule • Government/contractor interaction less focused • Requirements growth harder to control • May detract from more critical risk reduction efforts on critical subsystems in ground tests and simulations.

[a] F-22 was result of extraordinary effort by Lockheed late in the program. Without YF-23 competitive pressure, YF-22 prototype program would likely have accomplished considerably less. However, this competition was conducted under fixed price contracts and involved considerable contractor funding of the effort.

Lessons From Recent Prototyping Experience

When significantly new versions of airframe and flight control system configurations are to be developed, pre-E&MD prototypes serve as a powerful tool for risk reduction. However, for aircraft systems similar to already flown and operational airframe and control configurations and subsystem characteristics using existing engines or derivatives or modest incremental modifications of such engines, the benefits of pre-E&MD prototypes may not always justify the price in cost and schedule delay (which can also translate into cost). Thus, for example, there was no pre-E&MD prototype for the F-15 and little indication that such a prototype would have served a useful

purpose. Most of the development and operational problems encountered with the F-15 would not have been revealed during test of a pre-E&MD prototype. (The F100 engine for the F-15 was a significant step in engine technology and had a competitive ground test prototype program before full-scale development).

On the other hand, the F-16 embodied radically new aircraft stability interactions with electronic flight control (fly-by-wire) in combination with novel aerodynamic configuration features. Clearly the F-16 could be said to require a prototype test. Similarly, the F-22 represented a pioneering effort to integrate low-observable characteristics into a supersonic and highly maneuverable airframe configuration, and incorporated a number of aerodynamic and engine integration features outside the realm of previous aircraft design experience. Again, prototype flight testing was a prudent step in the development. The point is that air vehicle prototypes are not uniformly cost-effective as risk reduction tools in a development program. Their relative value depends on the degree to which the airframe configuration and engine installation features depart from the domain of recent experience.

Within the context of this knowledge, the Task Force examined possible prototyping strategies for the F/A-18E/F and the A/F-X.

Prototyping the F/A-18E/F

The Task Force could not find any basis for introducing flight vehicle prototype into the F/A-18E/F aircraft at the present stage of its E&MD program. The F/A-18E/F is not a high-risk program in terms of concept, design, performance or operational suitability. In many ways the F/A-18C/D can be considered a prototype of the F/A-18E/F. The aerodynamic and structural concepts for the F/A-18E/F are essentially the same as those of the F/A-18C/D. Aerodynamic and other design models and tools used in the F/A-18E/F program have been calibrated and validated using data from earlier F/A-18 flight testing. This has provided information of the kind that would be available from a flying prototype. Technical risks remaining in the program (e.g., weight) can only be confronted in the E&MD program with E&MD flight-test articles. The additional costs (in time and money) of disrupting the E&MD program and building early flying prototypes far outweigh the value of any potential risk reductions.

Milestones and exit criteria within the F/A-18E/F's E&MD phase can serve as necessary control points for committing large amounts of funding to production and significant production quantities. The Navy Program Review-1 (NPR-1) is the first program milestone associated with the commitment of long-lead production funding. The Navy plans to have completed an early operational assessment of the aircraft design based in part on flight performance of the first two E&MD aircraft prior to NPR-1. While some schedule adjustments may be needed to NPR-1 to accomplish this, the program phasing should continue to allow for sufficient evaluation of flight test and other data to provide sufficient confidence in the aircraft design and mission performance prior to commitment to production funding.

Prototyping the A/F-X

Current A/F-X requirements call for a level of design innovation that justifies a flying prototype before the start of E&MD. The A/F-X program is planned to follow an acquisition strategy that could accommodate competitive prototyping of the airframe and engine during Dem/Val. If the design competition leading to Dem/Val provides a clear winner, then only a single design might be prototyped. Because the A/F-X is likely to employ avionics concepts and common equipment from the F-22 program, avionics prototype testing in a flying testbed may be required only for selected components, systems integration and software.

APPENDIX A
TASK FORCE MEMBERS

DEFENSE SCIENCE BOARD TASK FORCE ON AIRCRAFT ASSESSMENT

Dr. John S. Foster, Co-chair,
TRW Inc.

Dr. Alexander Flax, Co-chair,
National Academy of Engineering

Mr. Robert R. Everett
The MITRE Corp.

Mr. Donald N. Fredericksen
Hicks & Associates, Inc.

Mr. David R. Heebner
Vice Chairman of the Board
Science Applications International Corp.

Mr. Milton A. Margolis
Logistics Management Institute

Adm. Wesley L. McDonald,
USN (Ret.)

Mr. Robert F. Nesbit
Technical Director, The MITRE Corp.

Mr. Robert N. Parker

Lt. Gen. Robert E. Pursley,
USAF (Ret.)

Dr. Richard J. Sylvester
Fellow, The MITRE Corporation

Gen. Larry D. Welch, USAF (Ret.)
President, Institute for Defense Analyses

Executive Secretary

Capt. Eric Vanderpoel, USN,
OUSD(A) Tactical Systems

DSB Liaison

CDR Stephen Wiley, USN,
OUSD(A) Defense Science Board

Working Group

Dr. J. Richard Nelson
Asst. Director, Cost Analysis and Research Division, Institute for Defense Analyses

Mr. Bruce R. Harmon
Institute for Defense Analyses

Mr. Joseph W. Stahl
Institute for Defense Analyses

Government Representatives

Dr. Spiros Pallas
OUSD(A)/Tactical Systems

Maj. Gen. Richard B. Myers
Director, Fighter, C2 and Weapons Programs,
ASAF(Acquisition)

Col Brian C. Dugle
Deputy Chief, Fighter Div.
Fighter, C2 and Weapons Programs Directorate
ASAF(Acquisition)

Mr. Larry Kreitzer
Office of the Assistant Secretary of the Navy
(Research Development and Acquisition)

Mr. Robert Thompson
Office of the Assistant Secretary of the Navy (Research Development and Acquisition)

Mr. Brian Long
Defense Intelligence Agency

Mr. Paul Scheurich
Defense Intelligence Agency

APPENDIX B
EXCERPT FROM THE NATIONAL DEFENSE AUTHORIZATION ACT

CONGRESSIONAL LANGUAGE

Defense Authorization Act for Fiscal Year 1993

(PL 102-484)

Section 902 Tactical Aircraft Modernization Programs.

(a) Funding Limitation Pending Certain Actions-

. . . .

(3) The Secretary of Defense has submitted to the congressional defense committees the technical assessments of the Defense Science Board that are specified in subsection (d).

(b) Applicability—Subsection (a) applies to the following tactical aircraft programs:

(1) The F-22 Advanced Tactical Fighter (ATF) program of the Air Force.

(2) The F/A-18E/F fighter program of the Navy

(3) The A-X medium attack aircraft program of the Navy.

. . . .

(d) DSB Technical Assessment.—The technical assessments to be undertaken by the Defense Science Board for purposes of subsection (a)(3) are the following:

(1) An assessment of the ways that current aircraft, upgrades to current aircraft, and new design aircraft can be modified or otherwise adapted so that a single aircraft type can be used by both the Air Force and the Navy in parallel missions.

(2) An assessment of the technical risks associated with the three tactical aircraft specified in subsection (b).

APPENDIX C
TERMS OF REFERENCE

DIRECTOR OF DEFENSE RESEARCH AND ENGINEERING

WASHINGTON, DC 20301-3010

5 JAN 1993

MEMORANDUM FOR CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Terms of Reference -- Defense Science Board Task Force on Aircraft Assessment

Section 902(d) of the National Defense Authorization Act for Fiscal Year 1993, Public Law Number 102-484, provides as follows:

> " (d) DSB Technical Assessment.- The technical assessments to be undertaken by the Defense Science Board for the purposes of subsection (a)(3) are the following:
>
> (1) An assessment of the ways that current aircraft, upgrades to current aircraft, and new design aircraft can be modified or otherwise adapted so that a single aircraft type can be used by both the Air Force and the Navy in parallel missions.
>
> (2) An assessment of the technical risks associated with the three tactical aircraft in subsection (b)."

Additionally, page 210 of the Senate report on the Department of Defense Appropriation Bill, 1993, Report 102-408, requests that the Department provide:

> " (d) the results of an examination of the advantages and disadvantages, especially in terms of program cost, schedule, and technical risks, of prototyping the F-18E/F and of competitive prototyping of AX; this examination must be conducted by an independent organization in no way connected with the Navy;"

I request you organize a Defense Science Board Task Force to conduct these technical assessments. Copies of the appropriate sections of the Public Law and report language are attached.

The scope of the Task Force effort should include the following considerations:

1. <u>AX, F-22, & F/A-18E/F</u>: The DSB shall examine the programs, plans, schedules, funding, and the maturity of the level of technology associated with AX, F-22, and F/A-18E/F programs and assess their feasibility of meeting their stated technical and programmatic objectives. AX and F/A-18E/F COEA and AX Development Options Studies will be briefed by the Navy as part of the review of the requirements. Level of technology

for stealth, avionics & sensors, airframe, and engine features will be viewed in terms of meeting schedules, costs, and requirements. Competitive prototyping on A-X and prototyping of the F/A-18E/F will be assessed to determine its impact on risk reduction with regard to potential cost implications.

2. <u>Current Aircraft</u>: The Navy and Air Force will brief the DSB on Pre-Planned Product Improvement (P3I) and major Engineering Change Proposals (ECPs) planned for current tactical attack/fighter aircraft. Included for current aircraft will be the F-15, F-16, AV-8B, F-14, F-117, F-111, A-10, A-6, and F/A-18 aircraft. Some upgrades/modifications will include new or improved avionics and engines. The DSB will assess the technical merits of further modifying these aircraft to meet other service needs, the attained risks, and the overall feasibility and desirability of such commonality. In performing tasks 1 and 2 above, the DSB will consider the current and projected threat; the current and projected force structure along with aircraft and missions as indicated by the Joint Staff report. The DSB will report whether the technology and potential threats warrant any reconsideration of the aircraft missions in light of potential cost savings and/or enhanced warfighting capability, afforded by new technology.

In order to meet the requirements of section 902(d), the DSB should submit its final report by February 24, 1993. The report should be so constructed that it can be submitted to congress without compromising any proprietary data or competition sensitive information.

The Director, Tactical Systems will sponsor this Task Force. Dr. John S. Foster, Jr. and Dr. Alexander Flax will serve as Co-Chairmen. CAPT Eric Vanderpoel, USN will be the Executive Secretary and CDR Stephen N. Wiley, USN will be the DSB Secretariat representative. The Director, Tactical Systems will make arrangements and provide funding for a support contractor, should one be required, and will fund all necessary travel.

VHR

Victor H. Reis

Attachments

APPENDIX D
TASK FORCE SCHEDULE

TASK FORCE SCHEDULE

21 January 1993	**Institute for Defense Analyses, Alexandria, VA**
0830	Kick-off - Dr. Foster
0830-0845	Standards of conduct Brief - Mr. Cal Voss
0845-0915	Executive Session - Led by Dr. Foster
0915-0930	Terms of Reference - Mr. Frank Kendall
0930-0945	Break
0945-1145	Missions and Requirements-USN&USAF
1145-1245	Lunch
1245-1445	Missions and Requirements-USN&USAF
1445-1500	Break
1500-1630	F-22 Program-Program Manager
1630-1730	Executive Session

22 January 1993	**Institute for Defense Analyses, Alexandria, VA**
0800-0830	Executive Session
0830-1000	F/A-18 Program-Program Manager
1000-1015	Break
1015-1130	Other Navy Upgrade Programs/Activities
1130-1145	Working Lunch Set Up
1145-1300	Other Air Force Update Programs/Activities
1300-1430	AX Program
1430-1445	Break
1445-1615	AX Program-Program Manager
1615-1700	Executive Session

4 February 1993	**Lockheed, Atlanta, GA (F-22 Program)**
0800-1230	Group Morning Session & Working Lunch
1230-1730	Split Technical Sessions

5 February 1993	**McDonnell Douglas, St. Louis, MO (F/A-18E/F Program)**
0800-1230	Group Morning Session & Working Lunch
1230-1730	Split Technical Sessions

11 February 1993	**Institute for Defense Analyses, Alexandria, VA**
0830-0930	Executive Session
0930-1030	Ge~ Larry Welch on parallel mission areas
1030-1100	[illegible] Alternative Mission Discussions
1100-1300	JIAWG Briefing
1230-1300	Working Lunch
1300-1400	USAF View on Commonalty (F-16 to MRF)
1400-1500	Executive Session
1500-1515	Break
1515-1730	Executive Session

TASK FORCE SCHEDULE (CONT'D)

12 February 1993	**Institute for Defense Analyses; Alexandria, VA**
0800-0930	A/F-X SubGroup I Briefing in IDA SCIF (Foster, Flax, Welch, Sylvester & Military Advisors
0945-1000	Executive Session
1000-1030	Affordability-USAF&USN Cost Data [AP&PI]
1030-1200	DSB Executive Session
1200-1230	Working Lunch
1230-1700	DSB Executive Session

18 February 1993	**Institute for Defense Analyses; Alexandria, VA**
0800-1500	DSB Members Review DSB Report and Prepare Briefing

APPENDIX E
REFERENCES

REFERENCES

[1] Conventional Systems Committee. "Integrated Program Assessment, F/A-18E/F." Secret, 27 April 1992.

[2] Conventional Systems Committee. "Advanced Tactical Fighter Technical Risk Assessment." Secret/Proprietary Information, June 1991.

[3] DIA, "The Fixed-Wing Tactical Air Threat—Worldwide for 2000–2005." Secret.

[4] "Independent Review of F/A-18E/F." Briefing.

[5] Harmon, B. R., L. M. Ward, and P. R. Palmer. "Assessing Acquisition Schedules for Tactical Aircraft." Institute for Defense Analyses, Paper P-2105, February 1989.

[6] Harmon, B. R., J. R. Nelson, N. I. Om, J. M. Sater, and A. W. Salerno. "Schedule Risk Assessments for Tactical Aircraft Programs." Institute for Defense Analyses, Document D-1214, December 1992.

[7] Tyson, K. W., J. R. Nelson, D. C. Gogerty, B. R. Harmon, and A. W. Salerno. "Prototyping Defense Systems." Institute for Defense Analyses, Document D-1097, December 1991.

[8] Nelson, J. R., B. L Retterer, and H. A. Cloud. "Organizational Options for Common Electronics Management." Institute for Defense Analyses, Document D-1159, December 1992.

APPENDIX D
TACTICAL AIR WARFARE TASK FORCE COMMENTS ON THE JOINT ADVANCED STRIKE TECHNOLOGY PROGRAM (JASTP)

OFFICE OF THE SECRETARY OF DEFENSE
WASHINGTON, D.C. 20301-3140

DEFENSE SCIENCE BOARD

2 OCT 1993

ME'' .ANDUM FOR UNDER SECRETARY OF DEFENSE (ACQUISITION)

THRU: CHAIRMAN, DEFENSE SCIENCE BOARD PG/C

SUBJECT: Tactical Warfare Panel Comments on Joint Advanced Strike Technology Program (JASTP)

This memorandum responds to your request for comments on the Joint Advanced Strike Technology Program (JASTP). We welcome this opportunity, since we share your desire and strongly support your efforts to establish a structure that will provide needed focus for technologies that could support development of new strike systems. We agree that JASTP is an appropriate vehicle to provide that focus. In this memorandum we will (1) relate to you our understanding of what JASTP is, (2) describe some additional factors you may wish to consider about the program's framework and relations to ongoing exploratory and advanced development activities, and (3) offer some suggestions with regard to management of the program.

We understand that JASTP will focus on bringing to fruition the aircraft oriented technologies that will support development of new strike platform(s) to include demonstrations of critical components and subsystems. Also to be included are air-launched weapon and delivery capabilities and surveillance/target engagement system interfaces necessary for effective strike system operations.

Future military situations will be more varied and less predictable than those we anticipated in the past in dealing with a Soviet threat. We believe that substantially different systems are required to provide a diverse array of options for dealing with this new defense environment. We believe too that advanced technologies could at the same time provide us with alternatives that lead to very different technical-military opportunities. With new and different system requirements and new and different technologies available for incorporation in new systems, we believe an exceptional opportunity now exists to explore the options more fully to seek to develop the most effective and affordable solutions.

We believe that development of the next strike system must consider a broad range of concepts for accomplishing strike warfare missions. Consideration must be given to a broad range of alternatives, for instance, a mix of off-board and on-board

sensors and information processing. Further, there should be a full exploration and development of strike system technologies focused on designing for producibility/supportability/ deployability.

The JASTP needs explicit attention to the development of operational concepts. Development and advancement of operational concepts should be equal in priority to advancement of technology. We, therefore, recommend that development and demonstration of operational concepts should be a key objective of the demonstration prototypes. It would also be helpful to establish a focal point for operational concepts in each Service.

Sustainment of program support and interest requires the definition of specific goals. These goals should be products associated with a well-defined schedule. For initiating the program, we would suggest the following interactive processes be carried out to define and plan the program leading to component and subsystem advanced developments and demonstrations:

- Definitions of alternative operational concepts to achieve needed capabilities,
- Identification of preferred system concepts,
- Identification of the technologies that support preferred system concepts.

In particular, in setting up prototype demonstrations, discipline should be exercised to limit the scope of any demonstration to one or at most two major innovations. The Task Force considered the relationship of JASTP to a number of ongoing programs that are aimed at next-generation aircraft and associated avionics and weapons that would feed into, complement, or be complemented by JASTP. For example, the Integrated High Performance Turbine Engine Technology (IHPTET) Program is a comprehensive engine technology program spanning 6.2 and 6.3 activities and intended to provide major improvements in aircraft engine performance by the turn of the century.

Similarly, the Joint Integrated Avionics Working Group (JIAWG) is intended to establish compatible architectures and a common modular approach to aircraft avionics. Although at present the long-term success of this approach across the spectrum of aircraft systems is not apparent (it having been implemented mainly in F-22 avionics), the general concept appears to have merit and it should continue to be pursued with such modifications as may be found necessary. JIAWG does not encompass major sensors such as radars, and JASTP should assure adequate coverage of these major subsystems as well as other components particularly with respect to their application to low-observable platforms. JASTP should, especially initially, extend and help provide focus for such programs as technologies advance toward maturation and application. The technology programs

should provide roadmaps to JASTP indicating the proper relationship between their ongoing and planned activities and JASTP.

Finally, we note that the planned management of JASTP is based on estabalishing a lead-service for the total program to be rotated every three years among the services. Thus far the nature and scope of this overall management function does not appear to have been defined. It seems to us that there is little to be gained by integrating detailed program management of such diverse technologies as propulsion and avionics and such diverse advanced components as radars and jet engines in a single office until such time as the integration into development of particular aircraft systems is imminent. We would suggest that the JASTP overall management serve primarily for resource allocation, delineation of requirements and standards, and overall program planning and coordination and that this joint program management function report directly to the Office of the Secretary of Defense. This overall joint program management should serve as a focal point for JCS/CINC and service views on operational factors and requirements. Specific major technology and component programs should be managed separately by joint offices with lead responsibilities and rotation cycles (if any) assigned to particular services as appropriate to the nature and schedules of applications, relationships to other ongoing technology programs, and the availability of the technical and management resources needed in program offices.

We would be happy to discuss our thoughts with you at your convenience.

John S. Foster, Jr.
Co-Chairman

Alexander Flax
Co-Chairman